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# STUDY OF THE ECONOMIC EFFECTS OF CHANGES IN AIR QUALITY

Charles R. Vars, Jr., et al

Oregon State University

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# Study of the Economic Effects of Changes in Air Quality

**Final Report**

***Air Resources Center***
**Oregon State University**

June 1972

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The following report summarizes research completed during the past three fiscal years (May 1969 - June 1972) under a contract with the Air Pollution Control Office, a unit of the Environmental Protection Agency, for a *Study of the Economic Effects of Changes in Air Quality.*

The report is concerned with measurement of the economic changes consequent to the introduction of various air pollution control policies. In particular, the report examines the impact of alternative policies to restrict open burning of agricultural fields in the Willamette Valley. This project was under the joint leadership of Dr. G. W. Sorenson and Dr. R. C. Vars, Associate Professors of Economics. Dr. Sorenson is the author of Appendix H of this report, while Dr. Vars is the author of the remainder of the report.

R. M. Alexander
Project Director

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A summary is presented of the research results of a three year study of the economic effects of changes in air quality. The study specified a conceptual model within which the benefits of controlling air pollution can be evaluated, as well as generated new testable hypotheses concerning the effects of air pollution on consumer activity. Implementation of the benefit-cost methodology consistent with the conceptual model and its associated hypotheses focused on the estimation of the various benefits and costs of controlling smoke produced by open burning of grass seed fields in the Willamette Valley. Eight appendices are attached which present theoretical and empirical materials, new, generally unappreciated theoretical results and empirical investigations which tested important hypotheses.

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# STUDY OF THE ECONOMIC EFFECTS
# OF CHANGES IN AIR QUALITY

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Corvallis, Oregon

1b

# PREFACE

This report summarizes the research results of a three year study of the economic effects of changes in air quality. The study specified a conceptual model within which the benefits of controlling air pollution can be evaluated, as well as generated new testable hypotheses concerning the effects of air pollution on consumer activity. Implementation of the benefit-cost methodology consistent with the conceptual model and its associated hypotheses focused on the estimation of the various benefits and costs of controlling smoke produced by open burning of grass seed fields in the Willamette Valley.

Although the conceptual framework presented in this report was not originally designed to supplement (and, in certain respects, complement) the frameworks employed in two recent reports to the Environmental Protection Agency, we believe that this report does present a useful conceptual framework intermediate to those proposed by the TRW Systems Group and the CONSAD Research Corporation.* Our extensions of the theoretical literature on the economic effects of pollution in appendices A, B, C, and H provide the foundation to the proposed conceptual framework and its associated hypotheses.

In contrast, the benefit-cost analysis of alternative open field burning control policies presented here contributes new findings for Oregon State University's continuing research program on field burning. Although in some respects the questions surrounding field burning are unique to the Willamette Valley, we would suggest that certain features of our empirical methodology may be usefully applied to other pollution problems.

During the course of this study, we received encouragement, guidance, and review from members of the faculty and staff at Oregon State University, the Air Quality Control Division of the Oregon Department of Environmental Quality, county property assessment offices in the Willamette Valley, and the Environmental Protection Agency. At Oregon State University, we are particularly indebted to the following individuals: Robert M. Alexander, Director of the Air Resources Center, for general guidance; Professors David O. Chilcote (Agronomic Crop Science) and Frank S. Conklin (Agricultural Economics) for extending our understanding of the Oregon seed industry and its practices, as well as providing data without which Part III of

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*Kenneth R. Woodcock, *A Model for Regional Air Pollution Cost/Benefit Analysis*, a report prepared for APCO, EPA under contract with the TRW Systems Group (McLean, Virginia: May 1971); and *An Economic Model System for the Assessment of Effects of Air Pollution Abatement* Volume I: The OAP Economic Model System Development and Demonstration), a report prepared for the Office of Air Programs, APCO, EPA under contract with CONSAD Research Corporation (Pittsburgh, Pa.: May 15, 1971).

this report could not have been undertaken; Professors Norbert A. Hartman (Statistics) and Robert G. Mason (Agricultural Economics) for important contributions to the design and analysis of the research on tourist behavior; Professors Lars Olsson, Ernest W. Peterson, and William P. Lowry (Atmospheric Sciences) for their advice, interest, and encouragement during the development of a pollution production for the Willamette Valley; Don Poole (Instructional Resources and Materials Center) for drafting the figures presented in Parts II and III and appendices A and B; and our colleagues in the Economics Department, Professors Donald Farness and Fred Miller (on leave to the Oregon Highway Division for providing the data on recreational activities undertaken by Willamette Valley residents and tourists that underlies Part IV of this report. At the Department of Environmental Quality, Air Quality Control Division, meteorologist Bruce Snyder generously provided assistance and data without which our work on pollution production functions and, hence, benefit estimation would literally have been impossible. At EPA, Thomas E. Waddell has supplied information and steady encouragement over the course of our research. Finally special mention must be given the exceedingly able research assistance provided by Jagjit Brar, who collected the data, conducted the statistical investigations, and prepared first drafts of materials which appear in appendices E and F. We further wish to acknowledge the substantive assistance of the Air Resources Center secretarial staff in the preparation of this report. We are especially grateful to Mrs. Susan Wilson who supervised the production of the report, and Miss Marjorie Lee Howe for her assistance in typing the report.

Agricultural field burning ten miles north of Eugene, near the Willamette River, August, 1970.
(Photo by C. Wilkins)

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## I. INTRODUCTION

### A. The Problem: Open Field Burning in the Willamette Valley

Oregon dominates United States production of certain grass seed crops, in large measure because Willamette Valley producers adopted the annual practice of open field burning to control seed diseases and to dispose of harvest residues.

> "In 1968 Oregon produced 41 percent of the total U.S. grass and legume seeds on approximately 308,000 acres. The value of Oregon's total seed crop to farmers was about 31 million dollars. The Willamette Valley accounted for 25 million dollars, or nearly 81 percent of the total state seed crop value. Nearly 43 percent of the total state seed crop value was in Linn County.
>
> Grass seeds were grown on about 250,000 acres at a value of 26 million dollars. Of this amount 86 percent, or 22.4 million dollars, was in the Willamette Valley. About one-half (13 million dollars) was in Linn County.
>
> Ryegrass seed was grown on 134,000 acres in 1968 at a value of nearly 13 million dollars--almost one-half of the total value of grass seed sales. Essentially all of the U.S. ryegrass seed is produced in the Willamette Valley, with 75 percent being grown in Linn County. Most ryegrass seed is grown on poorly drained soils on which alternative uses are quite limited. About 65 percent (87 thousand acres) of all ryegrass acreage is annual ryegrass. Perennial ryegrass is grown on the remaining 35 percent (47 thousand acres).
>
> Cleaning, sacking, and handling added about 12 percent, or 3.7 million dollars, to the value of the 1968 total seed crop. Blending and small packaging of grass seeds has been increasing within Oregon in recent years."*

Unfortunately, although field burning provides an effective and low-cost method of residue disposal and disease control, it also produces smoke in sufficient volumes to constitute a major air pollution problem for Oregon authorities. In fact, the Department of Environmental Quality has recently reported that, despite the decline in complaints from 1969 to 1971, field burning remains

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*Middlemiss, W. E. and R. O. Coppedge, *Oregon's Grass and Legume Seed Industry in Economic Perspective*, Special Report 284, Cooperative Extension Service, Oregon State University, Corvallis, April 1970. p. 7.

its major source of citizen complaint. Although most complaints reported in Table I.1 came from individuals and groups in the Eugene area, locations in the mid-Willamette Valley - e.g. Salem, Corvallis, and Lebanon - generated relatively large increases in complaints in 1970 as field burning south of these cities was purposely increased over past years when southerly winds were forecast. Overall, the DEQ reported that smoke and visibility reduction were the most frequent causes of complaint.*

Table I.1

Field Burning Complaint Summary

| Received by: | 1968 | 1969 | 1970 | 1971 |
|---|---|---|---|---|
| Department of Environmental Quality | 11 | 1645 | 306 | 113 |
| Mid-Willamette Valley Air Pollution Authority | 6 | 88 | 186 | 81 |
| Lane Regional Air Pollution Authority | 127 | 3409 | 1241 | 591 |
| Total | 144 | 5142 | 1733 | 785 |

Source: *Field Burning in the Willamette Valley - 1971*, Department of Environmental Quality, Air Quality Control Division Report, April 30, 1972, Table 2, p. 9.

More objective evidence of visibility restriction, smokiness, and air quality deterioration during recent summers is reported in Table I.2 and appendix D of this report. Table I.2 shows that smoke occurs with increasing frequency at both Eugene and Salem as summer progresses. It also provides evidence that the 1970 DEQ burning program reduced smokiness and increased visibility in Eugene while producing opposite effects for Salem in August -- a finding consistent with the statistical results we report in appendix D of this report.

Since field burning takes place between mid-July and late September, the visibility reductions associated with this agricultural practice occur during the height of the tourist and resident-vacation seasons in the Willamette Valley. Given the popular and widely prevalent belief that the desirability of outdoor recreation-type activities varies directly with visibility, it is generally believed that field burning adversely affects the Valley tourist industries. It is presumed that air quality deterioration leads tourists and residents to select different activities, alter their expenditures, etc.

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*Department of Environmental Quality, Air Quality Control Division, *Field Burning in the Willamette Valley, 1970*, staff report dated April 8, 1971, pp. 3-5.

## TABLE I.2

## Smokiness in Salem and Eugene

| | SALEM | | | | EUGENE | | | |
|---|---|---|---|---|---|---|---|---|
| | Year -'68 | '69 | '70 | '71 | '68 | '69 | '70 | '71 |
| **JULY** | | | | | | | | |
| Smoky Days | 3 | 6 | 4 | 4 | 3 | 5 | 3 | 3 |
| Smoky Hours | | | | | | | | |
| Visibility 6 mi. or less | 10 | 8 | 8 | 16 | 10 | 12 | 8 | 12 |
| Visibility 3 mi. or less | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 2 |
| Visibility 1 mi. or less | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **AUGUST** | | | | | | | | |
| Smoky Days | 5 | 10 | 10 | 5 | 4 | 11 | 7 | 4 |
| Smoky Hours | | | | | | | | |
| Visibility 6 mi. or less | 11 | 16 | 53 | 14 | 15 | 40 | 14 | 8 |
| Visibility 3 mi. or less | 0 | 3 | 16 | 2 | 8 | 30 | 3 | 3 |
| Visibility 1 mi. or less | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 1 |
| **SEPTEMBER** | | | | | | | | |
| Smoky Days | 15 | 8 | 6 | 6 | 17 | 9 | 6 | 3 |
| Smoky Hours | | | | | | | | |
| Visibility 6 mi. or less | 92 | 66 | 50 | 19 | 170 | 51 | 35 | 9 |
| Visibility 3 mi. or less | 18 | 16 | 10 | 1 | 62 | 42 | 1 | 1 |
| Visibility 1 mi. or less | 0 | 0 | 0 | 0 | 6 | 4 | 0 | 0 |
| **OCTOBER** | | | | | | | | |
| Smoky Days | 11 | 13 | 10 | 11 | 16 | 15 | 10 | 3 |
| Smoky Hours | | | | | | | | |
| Visibility 6 mi. or less | 53 | 85 | 65 | 59 | 67 | 39 | 47 | 5 |
| Visibility 3 mi. or less | 5 | 35 | 16 | 8 | 50 | 25 | 3 | 0 |
| Visibility 1 mi. or less | 0 | 0 | 0 | 0 | 8 | 3 | 0 | 0 |
| SEASON TOTAL SMOKY DAYS | 34 | 32 | 30 | 26 | 40 | 40 | 26 | 13 |

Source: Department of Environmental Quality, Air Quality Control Division, *Field Burning in the Willamette Valley - 1971*, staff report dated April 30, 1972, Table IV, pp. A-11.

Note: Smoky days are those days showing a restriction to visibility at the airport by smoke only, haze only, or smoke and haze on one or more hourly observations.

Smoky hours are those hourly observations showing restrictions to visibility by smoke only, haze only, or smoke and haze.

A weather element is listed as restricting visibility when it reduces prevailing visibility to six miles or less.

Consequently, many argue that a complete ban or some other stringent regulation of open field burning may raise incomes of the owners of specialized resources in the tourist industries while simultaneously improving air quality in the Willamette Valley.

Of course, some of the adverse effects of visibility reductions have already been somewhat reduced by the smoke management policy adopted in recent years by the Oregon Department of Environmental Quality, Air Quality Control Division. The DEQ has attempted to minimize visibility losses attributable to open field burning smoke in Eugene and Salem by controlling daily acreages burned according to prevailing and predicted meteorological conditions. This program has been reasonably successful (see Table I.2 and appendix D) in decreasing, though not eliminating, one major and well-established effect of open field burning smoke without directly affecting production practices or total acres burned.*

In contrast to smoke management, improvements in visibility obtained by partially or completely eliminating open field burning would increase total costs per acre in producing grass seed (see Table I.3) and/or significantly reduce yeilds per acre (see Table I.4). In addition to raising production costs, however, published and unpublished studies suggest that in the absence of extensive burning there would be (1) increases in the incidence of seed diseases, (2) decreases in seed purity, and (3) increases in seed cleansing costs.** Since the superior quality of Oregon seeds has been a major factor in the successful growth of the Oregon seed industry, increases in disease and impurities suggest that traditional markets for Oregon seeds would decline

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*This judgment should not be interpreted as indicating that either the DEQ staff or the authors of this report see no room for improvement in the DEQ smoke management program. Evidence presented in Part IV and appendix D suggests improvements are possible but unlikely to prove as substantial in the future as those achieved over the 1970 and 1971 burning seasons unless all burning in the southern half of the Valley is done under southerly wind conditions.

***Agricultural Field Burning in the Willamette Valley*, Air Resources Center, Oregon State University, Corvallis, January 1969; John R. Hardison, *Justification for Burning Grass Fields*, in Proceedings: 24th Annual Oregon Seed Growers Conference, Corvallis, 1964; and David O. Chilcote, Department of Agronomic Crop Science, personal letter with accompanying tables dated May 30, 1972.

TABLE I.3

A summary of increases in total costs per acre over open field burning with alternative residue removal techniques on selected grass seed crops.

| Alternative Residue Removal Techniques | Annual Ryegrass $/A | Perennial Ryegrass $/A | Highland Bentgrass $/A | Fine Fescue $/A | Merion Bluegrass $/A |
|---|---|---|---|---|---|
| A. Incorporation of residue into the soil | $21-$26 | | | | |
| B. Mobile field incinerator | $ 5-$10 | $ 5-$10 | $ 5-$10 | $ 5-$10 | $ 5-$10 |
| C. Mechanical removal of residues followed by field sanitation a/ | | | | | |
| 1. Bunching and Field Bucking | $12-$16 | $11-$14 | $10-$12 | $10-$12 | $ 9-$11 |
| 2. Stack Former and Mover | $15-$25 | $13-$21 | $11-$17 | $11-$17 | $11-$15 |
| 3. Chopper-Blower and Hauling b/ | $43 | $34 | $25 | $25 | $22 |
| 4. Baling and Hauling c/ | $24-$39 | $18-$28 | $18-$28 | $18-$28 | $16-$24 |
| 5. Field Cubing and Hauling d/ | $34-$68 | $34-$52 | $25-$37 | $25-$37 | $22-$31 |

a/ Costs include an $8/acre charge for use of a mobile field incinerator but exclude any expenses which may be required for residue utilization or disposal.

b/ Due to a lack of data, no range in costs were calculated. Only a custom rate of $10/ton for chopping, blowing, and hauling, and $8/acre for field sanitation were used.

c/ Projecting a range in baling and hauling costs of $6 to $12/ton with no swathing required.

d/ Projecting a range in cubing and hauling costs of $10 to $17/ton.

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Source: Conklin, Frank S. and R. Carlyle Bradshaw, *Farmer Alternatives to Open Field Burning: An Economic Appraisal*, Special Report 336, Agricultural Experiment Station, Oregon State University, Corvallis, October 1971, pp. 13.

## TABLE 1.4

### Effects of Various Seed Crop Residue Management Programs on Seed Yield, by Species, Treatment, and Sample Plot

| Species | 1966 | 1967 | 1968 1/ | 1969 | |
|---|---|---|---|---|---|
| Chewings Fescue | BE | BL | BE | BE | 100 |
| | BL | BE | BL | S | 82 |
| | CR | CR | CRP | CRP | 68 |
| | CR | CR | CR | CR | 56 |
| | S | S | S | S | 38 |
| Red Fescue | | BE | BE | BE | 100 |
| | | BE | BE | S | 96 |
| | | CR | BL | CR | 88 |
| | | CR | CR | CR | 78 |
| | | BE | R | R | 78 |
| | | S | S | S | 46 |
| Bentgrass | CRP | CRP | CRP | CR | 102 |
| | BE | BM | BE | BE | 100 |
| | BE | BM | S | BL2/ | 87 |
| | CR | CR | CR | CR | 75 |
| | S | S | S | S | 58 |
| Orchardgrass | CRP | CRP | CRP | CRP | 101 |
| | BE | BE | BM | BE | 100 |
| | CRP | CRP | CR | CRP | 98 |
| | CR | CR | CR | CR | 84 |
| | R | R | R | R | 78 |
| | S | S | S | S | 64 |
| Bluegrass | BE | BE | BE | BE | 100 |
| | BE | BE | R | BM | 95 |
| | BE | BE | S | S | 86 |
| | BE | BE | BM | S | 84 |
| | CR | CR | S | CR | 69 |
| | R | R | CS | S | 62 |
| Perennial Ryegrass | BE | BE | | | 100 |
| Location 1 | CRP | CRP | | | 100 |
| | BL | BE | | | 99 |
| | BL | BM | | | 84 |
| | CR | CRP | | | 76 |
| | S | BM | | | 70 |
| | CS | S | | | 60 |
| Location 2 | | BE | BL | | 101 |
| | | BE | S | | 87 |
| | | BM | BL | | 100 |
| | | CRB | CRB | | 94 |
| | | CR | CRP | | 86 |
| | | CSB | CS | | 85 |
| | | CR | CR | | 65 |
| | | CS | CS | | 60 |
| | | CS | CR | | 49 |

Source: David O. Chilcote, Department of Agronomic Crop Science, personal letter with accompanying tables, May 30, 1972.

1/ 1968 was a wet summer and burns were not as complete but subsequent yields were good.

2/ Poor burn and essentially like no removal.

BE - burned early (Aug.)

BM - burned mid season (Sept.)

*CR - chop removed straw and most of stubble

*CRP - chop removed straw and most of stubble and propaned (early to mid season)

*CS - chopped & spread (similar to no removal)

S - residue

without burning. For this reason as well as others, the development of the mobile field sanitizer must be regarded as crucial.*

Finally, we should note that Oregon's dominant position in the production of certain grass seed crops derives in large measure from soil and climate conditions wonderfully well-suited to grass production. Grass seeds are raised on poorly drained Amity and Dayton soils in the Willamette Valley. The top soils are excellent but have severe drainage problems caused by an almost impermeable layer of subsoil. During the winter rains (November to April), top soils are waterlogged, commonly creating cultivation problems in the spring. Grasses in contrast to other crops stand these wet-soil and spring conditions well, and their seeds mature nicely during the Willamette Valley's typical warm, dry summers. These special conditions mean, however, that few alternatives exist for these soils without substantial capital investments and/or specialized management skills.**

## B. An Overview of the Report

For all of the reasons indicated in the previous section, the pollution problem created by open field burning in the Willamette Valley is somewhat unusual and poses interesting analytical and empirical questions. In particular, the seasonal nature of field burning, the special soil and climatic conditions in the Valley, Oregon's dominant position in the U.S. grass seed industry, and the populations (resident and tourist) affected by field burning smoke combined to suggest difficulties not readily analyzed in previously developed conceptual frameworks for evaluating alternative policies for controlling air pollution. Consequently, we undertook to construct a conceptual framework appropriate to study the open field burning problem in Oregon. In the process of doing this, we developed both a conceptual framework and testable hypotheses with more broad applicability than was our original intention. Part II of this report presents that framework and its associated hypotheses in a very general and non-specific fashion intended to demonstrate: (1) the merits of a general equilibrium framework for the analysis of certain air pollution control problems; (2) new testable hypotheses concerning air pollution and consumption activity; and (3) how benefit-cost analytical techniques are applicable in a general equilibrium context where a public good (i.e., air quality) affects individual welfare.

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*Since 1970, the Department of Agricultural Engineering, Oregon State University, has pioneered in the development and testing of a mobile field sanitizer, which is pulled by a tractor and has an auxiliary engine to power the blower and hydraulic units. It is desinged to burn all residue and stubble in its path within a self-sustaining combustion chamber, thereby reducing smoke emissions 80-90 percent and unburned hydrocarbon emissions by 99 percent when compared with open field burning. Disease and impurity problems would probably not arise if mobile field sanitizers were generally used in the Willamette Valley.

**This is the conclusion reached in a careful study by Frank S. Conklin and R. Carlyle Bradshaw, *Farmers Alternatives to Open Field Burning: An Economic Appraisal,* Special Report 336, Agricultural Experiment Station, Oregon State University, Corvallis, October 1971, p. 14.

Parts III, IV, and V employ the conceptual framework and hypotheses presented in Part II as the mortar to bond the bricks of our benefit-cost analysis of alternative open field burning control policies together. Part III examines the costs of alternative control policies and provides estimates of their magnitudes for the various groups adversely affected by these policies. New and traditional measurement techniques are employed to determine the impacts of alternative control policies.

Part IV investigates the benefits of improved visibility in the Willamette Valley to residents and tourists. An optimal burning policy with no reduction in total acres burned is specified by employing a simple welfare function, and we develop an index to measure improvements in visibility under each control policy investigated. Further, we estimate the resident outdoor recreational benefits associated with visibility improvements under each policy. Rather surprisingly, a multi-variate statistical analysis of tourist survey data revealed no support for the hypothesis that tourist behavior is affected by air quality deterioration due to smoke from open field burning. Appendix H reports this study in detail and should be regarded as a major contribution (albeit negative) of this report.

Part V concludes the main text of the report by drawing together the "most reasonable" estimates of the benefits and costs of each policy. Although no evaluative indexes such as benefit-cost ratios are presented in Part V, the implicit net total, average, and marginal cost of each policy is presented. Undoubtedly our most interesting finding is that improvements in Willamette Valley visibility are produced under conditions of decreasing average costs.

Finally, a word concerning the appendices to this report. As already indicated, appendix H reports a major investigation of the effects of air quality changes on tourist and resident recreation behavior. Although other appendices are less massive than H, they provide theoretical and empirical materials without which the main report could not have been written. New or generally unappreciated theoretical results are reported in appendices A, B, and C; these results greatly influenced the structure and content of Part II. In contrast, appendices D, E, and F report empirical investigations which tested important hypotheses and ultimately served as the basis of our benefit and cost estimates in Parts III and IV.

# II. EXTERNAL DISECONOMIES, ENVIRONMENTAL QUALITY, AND BENEFIT-COST ANALYSIS

## A. Introduction

Although economists in recent years have devoted considerable attention to the economic consequences of external economies and diseconomies, the rapidly expanding literature remains incomplete in a variety of respects. Given the vast array of situations where externalities may conceivably be important, as well as the variety of analytical methodologies potentially applicable, no one could realistically expect the literature to cover all facets of the subject with equal facility and completeness. As we reviewed the literature in an attempt to develop a useful framework for investigating the consequences of controlling the pollution created by open field burning in the Willamette Valley, we discovered that the literature had examined pollution problems in situations hardly comparable to the one with which we were concerned. Thus, we developed a framework incorporating new hypotheses into a modified version of the standard general equilibrium model to establish a methodological framework within which benefit-cost analytical techniques may be applied to evaluate alternative public policies to improve environmental quality.

Comments on the three special features of this framework appropriately precede detailed specification of the production, consumption, and benefit-cost relationships in the model. The following observations are also intended to provide some perspective on why the model is presented as it is.

(1) The model was designed to focus attention on the effects of regulating pollution generated by an industry (as opposed to a firm) in a general equilibrium framework that explicitly allowed for interindustry flows of materials. This type of model (particularly when extended to become a genuine regional model) is appropriate in the present context because the Oregon seed industry produces an intermediate good on more than one-fourth of the agricultural land in the Willamette Valley for U.S. markets which it dominates. A general equilibrium methodology must underlie an evaluation of alternative programs for restricting open field burning because such programs appear likely to change production costs for individual Oregon seed growers, market prices of certain seeds, supplies of seed produced outside Oregon, and agricultural land values in the Willamette Valley.

Of course, other economists have examined external diseconomies in similarly specified models previously. In those presentations, however, the analysis differs from that presented below. Goetz and Buchanan, for example, usefully analyze technological external diseconomies contained within a single industry in a simple general equilibrium model without intermediate goods; they assert shifts in transformation curves which we derive, as well as ignore effects of external diseconomies on other industries and the "state of the environment." * Ayres and Kneese present a model which allows for interdependencies on a considerably greater scale than our model, but they also assert rather than demonstrate the importance of a general equilibrium approach that allows for interindustry flows of materials.** Here and in Appendices A, B, and C, we extend the theoretical literature on pollution control policy matters by deriving new results and emphasizing the application of benefit-cost analysis to environmental quality matters.

(2) Our model postulates that individuals have preferences among various "states of the world" which differ in terms of (a) consumption activities produced and consumed by individuals and (b) the state of the environment. Since activities which may or may not require the purchase of market goods are among the objects of individual concern, the model has direct applicability to the loss of visibility associated with open field burning smoke between mid-July and late-September in the Willamette Valley. This loss of visibility occurs at the height of Oregon's tourist season, fouling the environment and obscuring the scenic views that attract the highly mobile tourist population, and attracted many present residents, to the valley. Presumably the typical tourist's and resident's activities are affected by the visibility deterioration. Our model provides new hypotheses concerning environmental quality and consumer activities, as well as a methodological framework for conducting benefit-cost analysis of alternative public policies to improve environmental quality.

(3) The model includes a "state of the environment" function that relates pollution directly to environmental quality. This function permits derivation of the environmental quality frontier associated with alternative pollution control policies and alternative private goods outputs, as well as simultaneous consideration of all major impacts of pollutants --on production, consumption, and the environment. While fairly complex diagrams are employed here to derive this frontier, such diagrams are pedagogically useful in revealing relationships not clearly specified in the literature referred to above or elsewhere. Furthermore, as the empirical research presented in later sections of this report indicates, environmental quality frontiers can be estimated to show the relevant trade-offs necessary for rational decision-making on environmental quality matters.

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* C. J. Goetz and J. M. Buchanan, *External Diseconomies in Competitive Supply*, American Economic Review, Vol. LXI, No. 5 (December 1971), pp. 883-890.

** Robert V. Ayres and Allen V. Kneese, *Production, Consumption, and Externalities*, American Economic Review, Vol. LIX, No. 2 (June 1969).

## B. Production, External Diseconomies, and Environmental Quality

We postulate an economy with two outputs, x and y, each of which requires the employment of the two primary factors, capital (K) and labor (L), and the other good as inputs. Perfect competition, perfectly inelastic factor supplies, full employment, constant returns to scale, diminishing marginal rates of substitution between primary factors, and fixed proportions in intermediate input use are also assumed. It is further assumed that each industry imposes Pareto-relevant or technological external diseconomies on itself and/or firms in the other industry through their influence on technological production relationships, as well as on consumers, and thereby themselves and firms in the other industry, through their influence on the "state of the environment," as measured by some index Q.*

The two production functions are:

$$x = x_{P_x,\ P_y\ Q}(K_x,\ L_x,\ \bar{y}_x) \tag{1}$$

$$y = y_{P_x,\ P_y,\ Q}(K_y,\ L_y,\ \bar{x}_y) \tag{2}$$

where $K_i$ and $L_i$ are respectively the capital and labor inputs $(i = x,y)$, $\bar{y}_x$ is the amount of y used as input in the production of x, and $\bar{x}_y$ is the amount of x used as input in the production of y, where the bars indicate that intermediate inputs are used in fixed proportions. Let X and Y represent the net supplies of x and y available for consumption and/or trade, and let $a_x$ and $a_y$ respectively denote the fixed requirement of x per unit of y and of y per unit of x. Then, the productive capacity of the economy is defined by

$$X = x - a_x y \tag{3}$$

$$Y = -a_y x + y \tag{4}$$

$$\bar{L} = L_x + L_y \tag{5}$$

$$\bar{K} = K_x + K_y \tag{6}$$

---

*Although our model could easily be extended to cover situations where one or more consumption activities generate external diseconomies in production and/or consumption, expositional simplicity and irrelevance to the problem under consideration (open field burning in the Willamette Valley) suggested excluding consumption generated external diseconomies from the presentation here. We do indicate in a later footnote how such externalities could be introduced into the supply side of our model.

Following Vanek and others, $a_i$ is assumed constant, and the product $a_x a_y$ is assumed to be less than one. (The latter assumption is the Hawkins-Simon condition required to ensure that net outputs are positive.)

The supply side of our model is not completely specified by equations (3)-(6). At this point, equations (1) and (2) have not been interpreted, and three additional equations remain unspecified. Consequently, prior to completing the specification of our model, we interpret the meaning and significance of production functions (1) and (2).

The functional subscripts in production functions (1) and (2) are intended to indicate that pollution associated with the production of x and y, $P_x$ and $P_y$, and the "state of the environment," Q, are parameters of these functions. The subscripts indicate the existence of what here are termed technologically relevant, parametric external diseconomies. Such external diseconomies negatively affect firm and industry production functions in a fashion indistinguishable from what might be termed "negative technological progress." More precisely, this means that changes in $P_x$, $P_y$, and Q shift the production functions such that

$$\frac{d}{dP_i}\left(\frac{\partial i}{\partial I_i}\right) < 0 \quad \text{for} \quad P_i > P_i^* \geq 0,$$

$$= 0 \quad \text{for} \quad P_i \leq P_i^* \geq 0,$$

$$\frac{d}{dQ}\left(\frac{\partial i}{\partial I_i}\right) > 0 \quad \text{for} \quad Q < Q^* \leq Q_{max}$$

$$= 0 \quad \text{for} \quad Q \geq Q^* \leq Q_{max}$$

where $i$ = $x$, $y$,

$I$ = $K$, $L$, $\bar{x}$ or $\bar{y}$,

$P^*$ = threshold amount of pollution beyond which pollution generates parametric external diseconomies in production,

$Q^*$ = threshold value of "state of the environment" index below which further environmental degradation generates parametric external diseconomies in production, and

$Q_{max}$ = maximum attainable value for environmental quality on the "state of the environment" index.

Note that this characterization of parametric external diseconomies explicitly introduces the often-observed threhold phenomena: namely, certain threshold levels must be attained before an externality has a discernible impact on the marginal productivity of inputs, $I_i$. Thus, our model explicitly allows for situations where particular pollutants are technologically irrelevant when produced in small quantities but technologically relevant when produced in amounts exceeding their respective thresholds. Similarly, it should be noted that we have deliberately refrained from any statement concerning rates of change in marginal products once thresholds are attained because this would involve assumptions concerning what are fundamentally empirical matter.

Three additional equations are required to complete the specification of the supply side of our model. Equations (7) and (8) are the pollution production functions associated with the production of x and y:

$$(7)\qquad P_{xj} = P_{xj}\,(K_x,\ L_x,\ \bar{y}_x,\ x) \qquad j = 1,\ \ldots,\ n$$

$$(8)\qquad P_{yk} = P_{yk}\,(K_y,\ L_y,\ \bar{x}_y,\ y) \qquad k = 1,\ \ldots,\ m$$

Notice that here we place no restriction on the number of types of pollutants associated with the production of x and y. Moreover, as before, we explicitly allow for the existence of thresholds

$$\begin{aligned} \frac{\partial P_{ir}}{\partial M_i} &> 0 \quad \text{for } M_i > M_i^* \geq 0 \\ &= 0 \quad \text{for } M_i < M_i^* \geq 0 \end{aligned}$$

where $i = x, y$, $r = j, k$, and $M = K, L, \bar{x}, \bar{y}, x, y$, without specifying in detail the characteristics of the pollution production functions.* Our own empirical investigations (reported in Appendix D) suggest that considerable caution in this regard is essential.

Finally, equation (9) indicates the relationship between some unspecified index measuring "the state of the environment," Q, and the various types of pollutants generated by the production of x and y:

$$(9)\qquad Q = Q(P_{x1},\ \ldots,\ P_{xn};\ P_{y1},\ \ldots,\ P_{ym})$$

where "the state of the environment" is a pure public good (in the Samuelsonian sense) enjoyed by producers and consumers alike. Although our "state of the environment" production function is similar to the usual production function in the sense that alternative combinations of pollutants (inputs) can produce the same "state of the environment" (output), we impose no restrictions on the function other than the following:

---

* The inclusion of final outputs available for consumption, X and Y, as arguments in equations (7) and (8) would introduce consumption-generated externalities potentially affecting production and the "state of the environment."

$$\frac{\partial Q}{\partial P_{ir}} = 0 \quad \text{for} \quad P_{ir} \leq P^{**}_{ir} \geq 0$$

$$\frac{\partial Q}{\partial P_{ir}} < 0 \quad \text{for} \quad P_{ir} > P^{**}_{ir} \geq 0$$

and

$$Q = Q_{max} \quad \text{where } \underline{\text{all}} \quad P_{ir} \leq P^{**}_{ir} \geq 0.$$

We assume that (a) there is some maximum attainable value for any realistic and well-defined "state of the environment" index but that (b) empirical investigations are required to determine relevant pollutant thresholds, marginal rates of substitution among pollutants, and the negative environmental returns to scale of pollution.

Equations (1) - (9) and their respective conditions establish the functional relationships underlying the supply side of our model of an economy where pollution is uncontrolled. However, before investigating the impact of various pollution control policies on supply conditions, we derive the transformation curve (in X-Y-Q space) for an economy with no pollution abatement activity. For expositional and geometric simplicity, we assume henceforth that (1) the "state of the environment," Q, is affected by two pollutants, $P_{x1}$ and $P_{y1}$, generated by production of x and y and that (2) industry x generates a technologically relevant external diseconomy for industry y. Given these assumptions, Figure II. 1 is used to derive the X-Y-Q transformation curve for an economy without pollution controls, U'U, present in Figure II. 2.

The northwest quadrant of Figure II. 1 indicates the dimensions of the Edgeworth-Bowley production box diagram, OKO'L, and the positions of the gross and net output transformation curves, ZPZ' and FP'F', respectively, for our model. Each point on the net output curve corresponds to a particular point on the gross output curve (for example, net output combinations F, P', and F' require gross output combinations Z, P, and Z', respectively), while the shape of the gross output curve results from our assumption that industry x generates a technologically relevant external diseconomy for industry y.* Thus, the net output transformation curve, FP'F', allows for inter-industry flows of materials and a production-generated external diseconomy despite its apparent normal properties.

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*The first section of Appendix A provides derivations of the gross and net transformation, or production possibility curves, while the third section of Appendix A specifies the impact of technologically relevant external diseconomies on production possibilities and derives a curve with a shape similar to the gross output curve in Figure II. 1. Note that the unusual shape of the gross output transformation curve does not result in an unusually shaped net output curve in Figure II. 1 because we have assumed $a_y$ to be relatively large. Here, and in Appendix A, production functions are assumed to be homogeneous of degreee one in order to facilitate graphical presentation of our principal results.

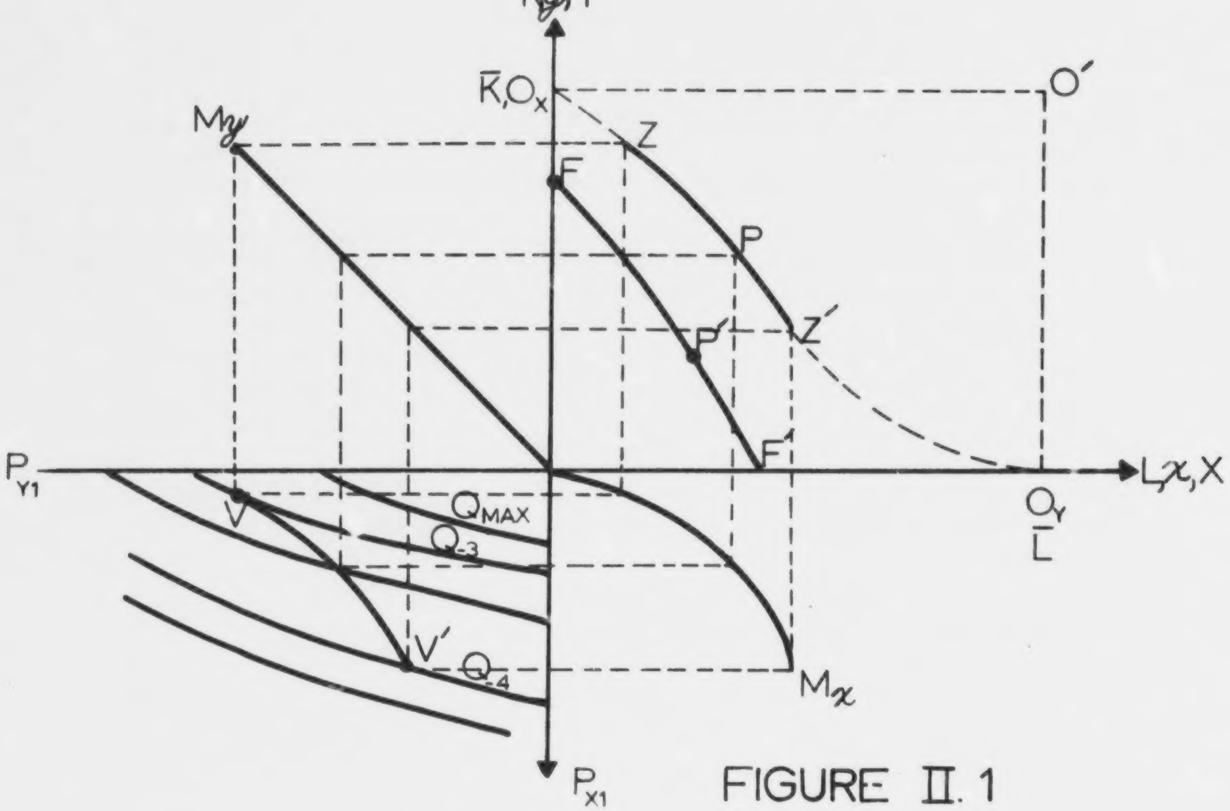
K,y,Y
K̄,O_x
O'
M_y
Z
F
P
P'
Z'
F'
P_Y1
L,x,X
V
Q_MAX
Q_3
O_Y
L̄
V'
Q_4
M_x
P_X1

FIGURE II. 1

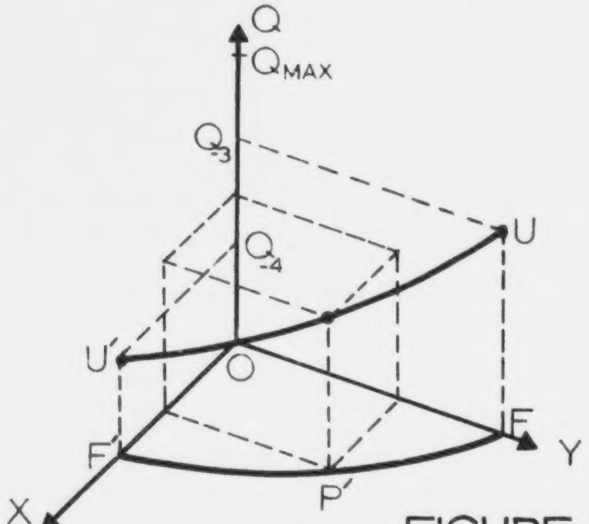
Q
Q_MAX
Q_3
U
Q_4
U'
O
F
Y
F'
X
P'

FIGURE II. 2

The northwest and southeast quadrants of Figure II. 1 depict the assumed pollution production functions associated with the production of y and x, respectively. Although our assumption that $P_{y1}$ per unit of y is constant at all levels of output probably corresponds to the normal view of pollution, we assume that $P_{x1}$ per unit of x steadily increases the total amount of pollutants produced. Where input proportions matter, as they appear to do in many instances, it seems unreasonable always to postulate the pollutants are produced in strict proportion to output.*

Projecting horizontally and vertically from points on the gross output transformation curve to the pollution production functions, $OM_x$ and $OM_y$, and then projecting once more to determine curve VV' in the southwest quadrant of Figure II. 1, we obtain the combinations of pollutants that determine the "state of the environment" associated with each combination of gross and net outputs (for example, points V and V' correspond to Z and Z', which in turn correspond to F and F', respectively). Given a "state of the environment" production function (depicted by curves $Q_{max}$, $Q_{-1}$, $Q_{-2}$, etc., which represent sets of alternate pollutant combinations resulting in successively lower quality environments), the pollutant combinations along VV' may be translated into index numbers measuring the quality of the environment.

Figure II. 2 summarizes the supply side of the model (sans pollution controls) in transformation curve UU' by plotting the X-Y-Q results developed in the northeast and southwest quadrants of Figure II. 1. The transformation curve UU' is important principally because it is one edge of the net output/environmental quality transformation surface that we later argue is required to measure the costs of pollution control properly. In fact, truly useful benefit-cost evaluations of alternative feasible control policies is impossible without such a transformation surface. Therefore, we next indicate how the relevant transformation surface can be derived by generating X-Y-Q transformation curves under alternate pollution control policies. This procedure has four advantages: (1) it is pedagogically useful in demonstrating the various impacts of pollution control policies in a general equilibrium setting; (2) it facilitates explanation of the concept of a "dominant policy"; (3) it indicates why constraints that reduce feasible policy options, and/or the scale on which policies may be undertaken, may result in avoidable inefficiencies; and (4) it demonstrates the major property of the relevant transformation surface, namely, that an increase in X, Y, or Q, jointly or in pair, is possible only with a decrease in one or both of the remaining items.**

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*For a critical analysis of the usual view that output and waste products (i.e., pollutants) are produced in fixed proportions, see Richard A. Tybout, *Pricing Pollution and Other Negative Externalities*, The Bell Journal of Economics and Mangement Science, Vol. 3, No. 1 (Spring 1972), pp. 252-266. Tybout refutes the "neutrality of bribery or compensation" argument; he does not, however, adopt the general equilibrium approach to pollution matters suggested in this report.

**Combinations of X, Y, and Q on the "relevant transformation surface" share the property of being technically efficient in the Paretian sense; each point on the surface describes an X-Y-Q combination such that X,Y, or Q individually or jointly cannot be increased without some decrease in one or both of the remainder.

Suppose industry x changes its production function (perhaps because of pollution control legislation), thereby (a) entirely eliminating the external diseconomy it previously imposed on industry y and (b) partially reducing $P_{x1}$ per unit of x. The effects of such a production process change to reduce pollution are described with the aid of Figures II.3 and II.4. Since such production process changes are properly viewed as negative technical progress, gross and net output curves ZZ' and FF' would shift to $Z_cZ_c'$ and $F_cF_c'$, respectively, while the pollution production function of the x industry would shift from $OM_x$ to $OM_{xc}$.* By projecting horizontally and vertically from quadrant to quadrant as before, the new environmental quality frontier, $V_cV_c'$, associated with the $Z_cZ_c'$ and $F_cF_c'$ transformation curves is obtained in the southwest quadrant of Figure II.3. In this instance, the production process change in the x industry improves the "state of the environment" regardless what composition of output is ultimately produced. Also note that this would be true even if the production process change had not reduced $P_{x1}$ per unit of x. Thus, we observe in Figure II.4 that $U_cU_c$ is above but closer to the vertical axis. Output would be sacrificed for an improved environment.

In contrast to the impact of production process changes, decisions to commit resources to pollution abatement activity shift the transformation curves and environmental quality frontier rather differently. This is the case because public pollution abatement activity uses resources and thereby reduces resources available for production (and hence pollution) without directly affecting the pollutant-generation characteristics of production.** In Figure II.5, resources devoted to pollution abatement

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*See appendices A and B for derivations of the shifts in the gross and net output curves shown in Figure II.3. One of the important propositions demonstrated in appendix B is that production process change in one industry affects maximum feasible outputs in other industries which employ the process-changing industry's output as an input. Consequently, the inward shifts of the gross and net output transformation curves depicted in Figure II.3 are not incorrect, though at first blush they may appear unusual to the reader unfamiliar with general equilibrium models that explicitly allow for inter-industry flows of materials.

** Public pollution abatement activity by itself affects pollutants generated in private production only indirectly via the changes in factor proportions it induces in the private sector. Only where aggregate factor proportions in the private sector are unaffected by public abatement activity will such indirect (positive or negative as the case may be) effects be entirely absent. Figure II.5 is constructed on the assumption that factor proportions are unaffected by pollution abatement activity and, therefore, it exhibits only the direct effects of such activity as discussed in the text.

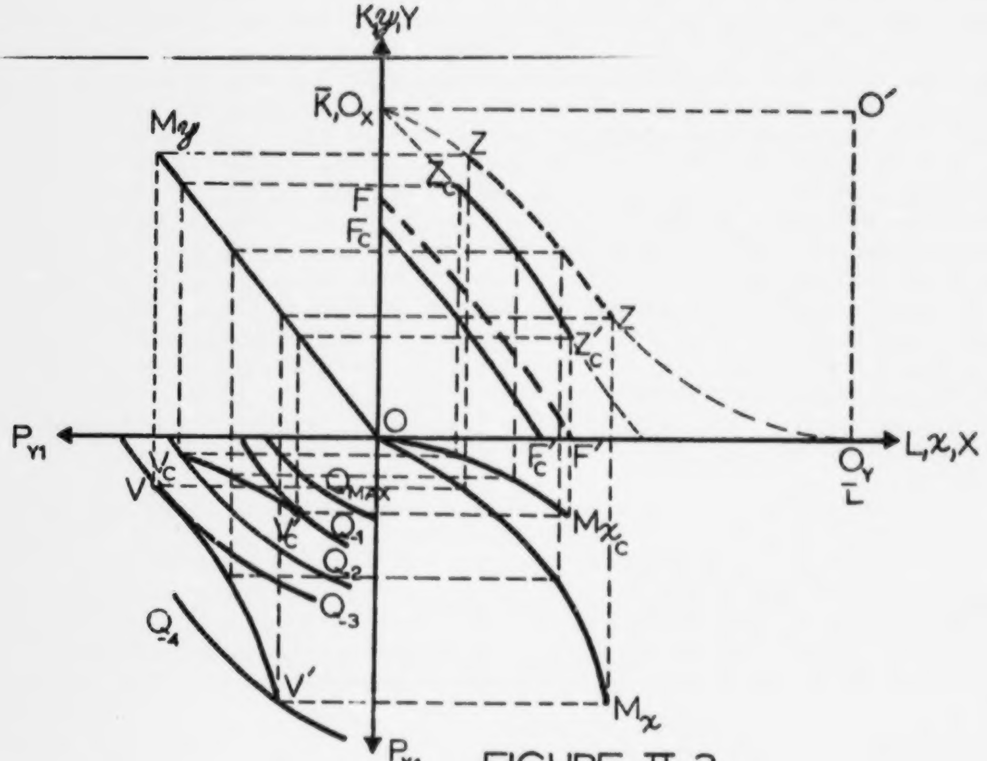
K,y,Y
$\bar{K}$,$O_x$
O'
$M_y$
Z
$Z_c$
F
$F_c$
Z'
$Z_c'$
O
$P_{Y1}$
L,x,X
$F_c'$
F'
$O_Y$
$\bar{L}$
$V_c$
V
$Q_{MAX}$
$V_c'$
$Q_{-1}$
$Q_{-2}$
$Q_{-3}$
$Q_{-4}$
$M_{x_c}$
V'
$M_x$
$P_{X1}$

FIGURE II. 3

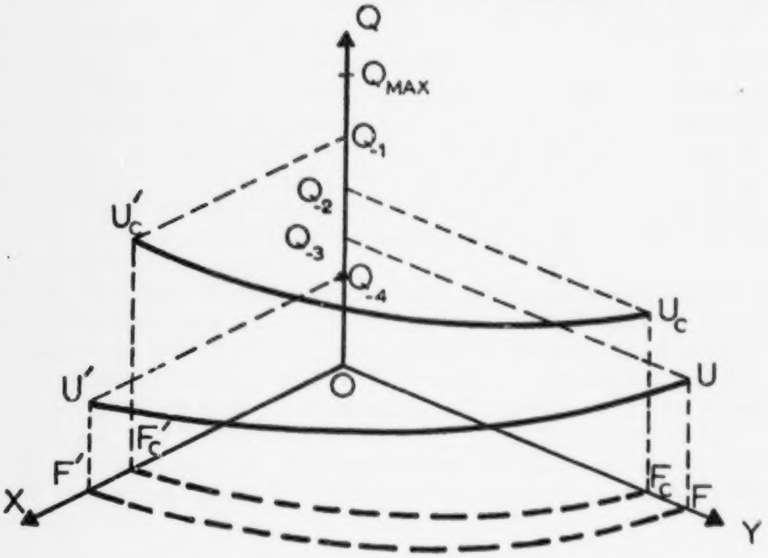
Q
$Q_{MAX}$
$Q_{-1}$
$Q_{-2}$
$Q_{-3}$
$Q_{-4}$
$U_c'$
$U_c$
U'
U
O
$F_c'$
F'
$F_c$
F
X
Y

FIGURE II 4

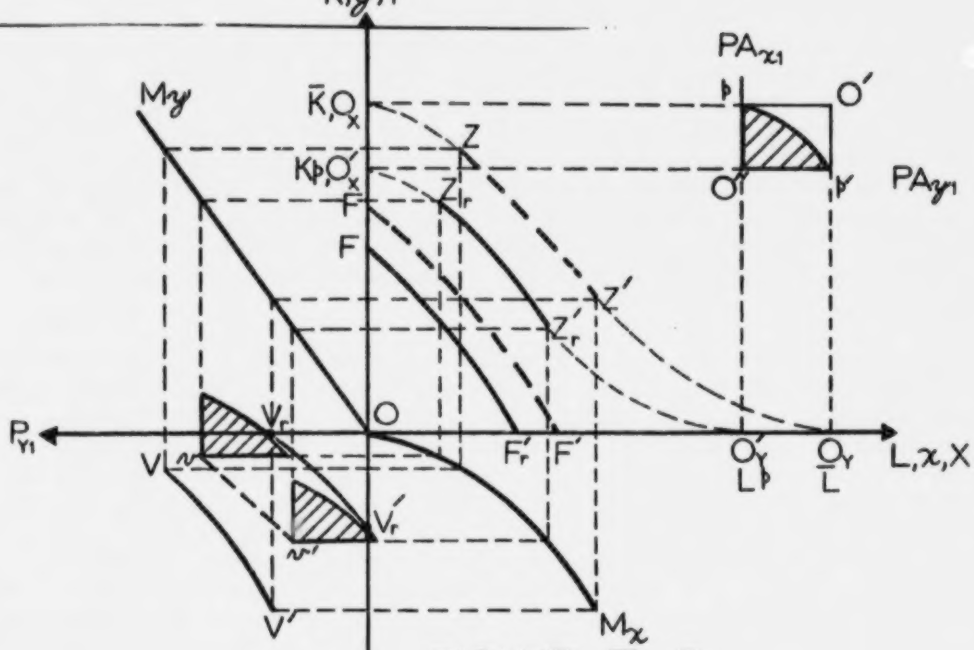
K, y, Y
My
K̄, O_x
Z
Kp, O'_x
Z_r
F
F
Z'
Z'_r
O
P_Y1
V_r
V
v
V'_r
v'
V'
M_x
P_x1
F'_r
F'
O'_Y
Lp
O_Y
L̄
L, x, X
PA_x1
p
O'
O
p
PA_y1

FIGURE II. 5

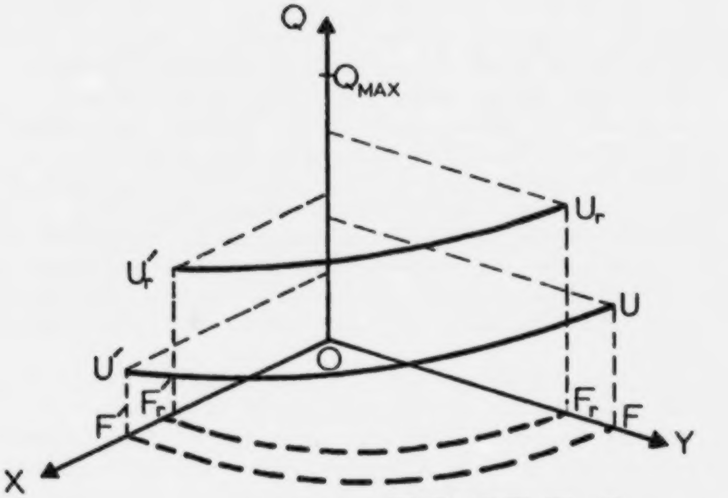
Q
Q_MAX
U_r
U'_r
U
U'
O
F'_r
F'
F_r
F
Y
X

FIGURE II. 6

activities ($K_p\bar{K}$ and $L_p\bar{L}$) provide abatement opportunities indicated by the curve pp', where pollution abatement "outputs", $PA_{x1}$ and $PA_{y1}$, are measured in the same units as the pollutants, $P_{x1}$ and $P_{y1}$, respectively. The reduction in available private factor supplies shifts gross and net output transformation curves inward to $Z_rZ_r'$ and $F_rF_r'$, respectively. These shifts alone move the environmental quality frontier from VV' to vv', while efficient pollution abatement shifts the environmental frontier to $V_rV_r'$ (which is obtained by sliding o"pp' at point o" along vv'). As in the case of the production process change in the x industry, however, summary Figure II.6 reveals that output must be foregone to achieve an improved "state of the environment" by public pollution abatement activity.

The similarity in our findings for these two pollution control methods does not imply that society would always be indifferent between the policies. In fact, ruling out political, social and income redistributional questions, it can easily be shown for certain ranges of outcomes that technical efficiency considerations alone are sufficient to select one policy over the other, while over other ranges no decision among policies can be made without knowledge of the decision-maker's valuations of private goods and environmental quality. We employ Figures II. 7 and II.8 to demonstrate that this view is correct. These figures represent the transformation curves and environmental quality frontiers associated with both policies described earlier; they are labelled identically to the earlier figures.

Figures II.7 and II.8 reveal that technical efficiency criteria are sufficient to select between industry x production process change and public pollution abatement activities only if the desired output level of Y lies in the range $OY_N$ to $OY_T$. Over that range of outputs on $U_rU_r'$ (or $F_rF_r'$), outputs of X and Y are larger and the "state of the environment" better than those attainable on $U_cU_c'$ (or $F_cF_c'$). Thus, production process change in industry x may be said to be dominated (i.e., is clearly inferior to) public pollution abatement activities at the postulated scale over the range $OY_N$ to $OY_T$. In contrast, with outputs of Y less than $OY_N$ or greater than $OY_T$ environmental quality varies inversely with aggregate output. Given the composition of goods output over these ranges, knowledge of the decision-maker's valuations of private goods and environmental quality is required to predict which method would be selected if these methods were the only ones under consideration.

Note, however, that although $U_rU_r'$ in its entirety could conceivably lie on the X-Y-Q transformation surface associated with technically efficient pollution control methods, only two sections on $U_cU_c'$ (namely $U_c'G$ and $EU_c$) could conceivably be on that transformation surface. Since other pollution control methods (individually or in varying combinations) could dominate every section along $U_rU_r'$ and $U_cU_c'$, one can only conceive--not predict with certainty--of particular points on $U_rU_r'$ and $U_cU_c'$ actually appearing on the net output/environmental quality transformation surface associated with technically efficient pollution control policies. (We amplify on this point below.)

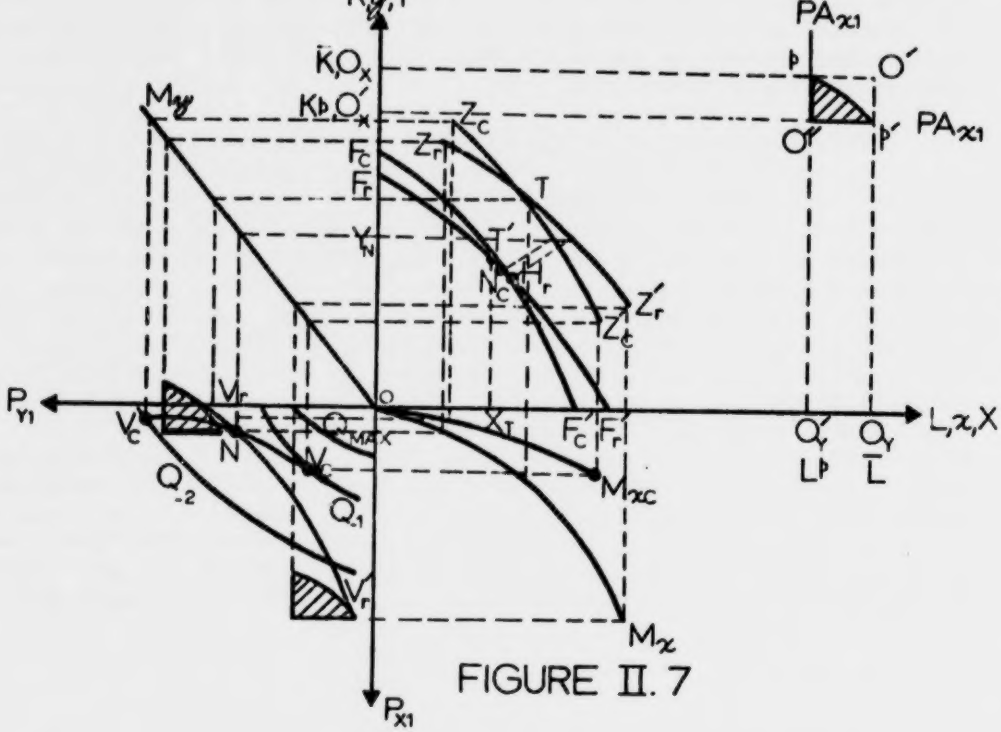
Ky, Y
PAx1
K, Ox
O′
Kp O′x
My
Zc
O′
p′
PAx1
Fc
Zr
Fr
T
YN
T′
Nc
Hr
Z′r
Z′c
Py1
Vr
O
XT
F′c
Fr
O′y
Oy
L,x,X
V′c
QMAX
N
Vc
Lp
L
Mxc
Q-2
Q1
V′r
Mx
Px1

FIGURE II. 7

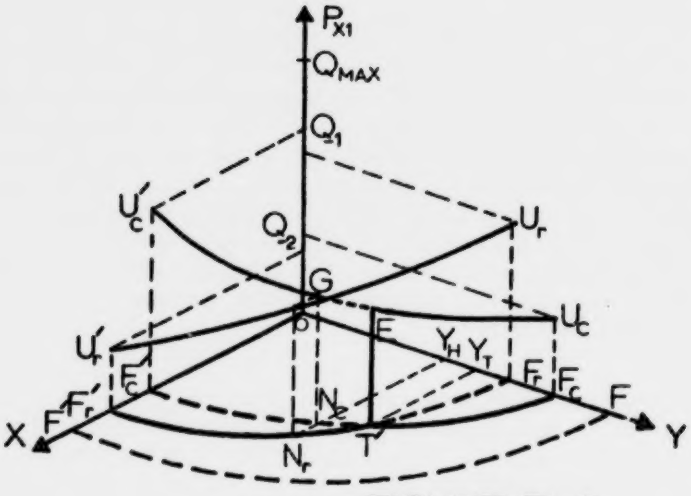
Px1
QMAX
Q1
U′c
Ur
Q2
G
O
Uc
U′r
E
YH
YT
Fc
Fr
Fc
F
Fr
F
Nc
X
Y
Nr
T′

FIGURE II. 8

To this point, only the effects of two particular pollution control methods undertaken at specified scales have been examined. We have neglected the impact of (1) the full range of control methods, (2) operated at all feasible scales, and (3) combinations of the various control methods operated at their respective efficient scales. We now turn to these tasks.

Direct regulations of the x industry production function and public pollution abatement activity constitute only a subset of the vast array of taxes, subsidies, regulations concerning pollutant emissions, production methods, product standards, waste treatment methods and performance standards, etc. available to reduce if not eliminate pollution and environmental degradation generated by production activity. Moreover, each pollution reduction method or policy can be pursued singly or in combination with others at varying scales and with varying effectiveness.* To take a particularly obvious case, consider public pollution abatement activity which conceivably could be undertaken on almost any scale provided there is public willingness to forego theprivate outputs that would be sacrificed as factor supplies available for private production decreased. Referring once more to Figures II.5 and II.6, if public pollution abatement activity were steadily increased without changing factor proportions in the private sector, gross and net output transformation curves would necessarily shift toward the origin steadily, as would the environmental frontier also.** The X-Y-Q combinations associated with these shifts would generate a transformation surface similar to the $UU'U'_mU_m$ surface depicted in Figure II.9.*

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*Of course, the framework we have specified here can encompass any pollution control method or policy which affects (1) relative product and/or factor prices, (2) factor supplies, (3) production functions, (4) pollution production functions, and/or (5) private and public pollution abatement facilities or activities. Since little ingenuity is required to introduce changes of these sorts into the model, or to represent them in diagrams of the type developed here, we are content merely to note that the only pollution reduction policies for which our model ultimately provides little guidance is where product quality is changed for pollution control or reduction. Since product quality problems are generally handled badly in most models, we simply admit our inability to make a substantive contribution to the study of product quality variation in a general equilibrium context.

**To avoid inefficiency and peculiarly shaped private output transformation curves, we do not require that the marginal rate of technical substitution between factors in public pollution abatement activities equal the rate of substitution in the private sector. Thus, we assume that public pollution abatement activities are efficient in a broader sense than usual and thereby avoid theproblems created by the standard efficiency rule when applied to the production of public goods. See appendix C for a discussion of these matters.

This transformation surface is of interest for a variety of reasons. At the most fundamental and obvious level, (1) $UU'U'_mU_m$ shows the net output/environmental quality combinations available in an economy restricted (for some reason) to public pollution abatement activities as the only means of controlling environmental quality. The implications of policy restrictions are discussed in detail below. (2) The external diseconomies generated by industry x negatively affect industry y output at all points on the surface, including $UU_rU_m$ where final output of x is zero. This is the case because x is a material input employed in the production of y, and therefore output of x, and hence pollution generated by the production of x, is positive where final output X is zero. (3) Recalling out earlier discussion and definition of policy dominance, (2) implies that certain (possibly all) sections of $UU'U'_mU_m$ are dominated by at least one (and possibly more) other pollution reduction methods. Consequently, only those sections of $UU'U'_mU_m$ that dominate the transformation surfaces associated with all other pollution reduction methods (individually or in varying combinations) become sections on the transformation surface relevant for policy selection, i.e., the envelope of all transformation surface sections associeated with absolutely dominant pollution reduction methods.

Except in rare circumstances, however, the Tinbergen-Theil theory of economic policy (as extended by Brainard) would suggest that the envelope transformation surface relevant for policy purposes would not include any sections of the transformation surfaces associated with a single pollution reduction method.** This conclusion follows as a direct application of the two major lessons of the theory of economic policy. Under conditions of certainty, in general the attainment of n objectives requires n instruments (pollution reduction methods here), and where more than n instruments are a available, only n instruments need be selected. Under conditions of uncertainty, however, these conclusions do not hold. Instead, the portfolio of instruments with the lowest coefficient of variation would be selected, and this portfolio would generally include the use of all available instruments. These findings suggest that in an economy where X, Y, and Q (at a minimum) matter in the selection among pollution reduction methods, single methods would typically be inferior to combinations of methods. Therefore, we conclude that, in general, the envelope transformation surface relevant for policy purposes may be expected to lie entirely above the transformation

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*Although Figure II.9 is drawn on the assumption that public pollution abatement activities, if undertaken on a sufficiently large scale without changing aggregate factor proportions in the private sector, would raise the state of environmental quality to its feasible maximum, such an assumption may be factually incorrect. Certainly such an assumption would be erroneous for certain other pollution reduction methods and the transformation surfaces associated with those methods would approach coincidence with the Q-axis below $Q_{max}$.

**For an outstanding summary and extension of the Tinbergen-Theil theory of economic policy, see William C. Brainard, *Uncertainty and the Effectiveness of Policy*, American Economic Review, Vol. LXII, No. 2 (May 1967), pp. 411-425.

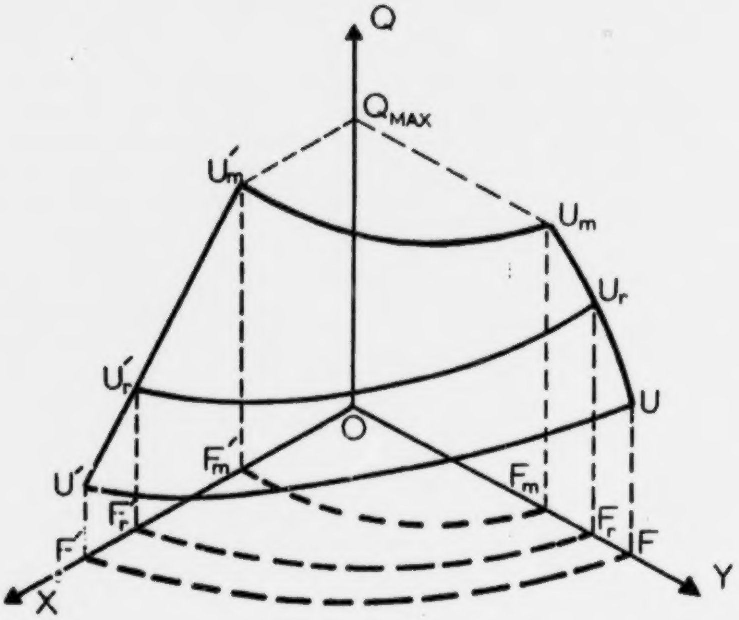
Q
$Q_{MAX}$
$U'_m$
$U_m$
$U_r$
$U'_r$
U
O
$F'_m$
$F_m$
$U'$
$F'_r$
$F_r$
$F'$
F
X
Y

FIGURE II. 9

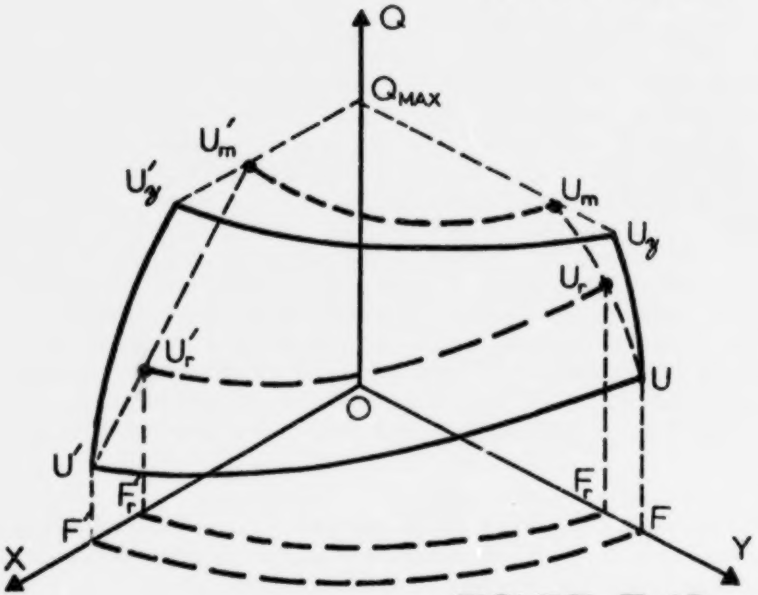
Q
$Q_{MAX}$
$U'_m$
$U'_y$
$U_m$
$U_y$
$U_r$
$U'_r$
U
O
$U'$
$F'_r$
$F_r$
$F'$
F
X
Y

FIGURE II. 10

surface associated with any single pollution reduction method. Figure II.10 illustrates this conclusion by showing that the envelope transformation surface relevant for pollution control policy selection, $UU'U_z'U_z$, completely dominates the public-pollution-abatement-activity transformation surface, $UU'U_m'U_m$ (from Figure II.9), except along $UU'$. *

Moreover, it follows that political, social, income and/or wealth distribution, etc., constraints that reduce the set of technologically feasible policy options, and/or restrict the scale on which particular policies may be undertaken, would necessarily eliminate some, though perhaps not all, dominant policy combinations. For this reason, one would expect the politically, socially, or distributionally constrained transformation surface to be partly, but rarely entirely, interior to the technically efficient envelope transformation surface described previously, and net output and/or environmental quality may be sacrificed to attain political, social or distributional objectives. These possibilities can be illustrated with the aid of Figure II.11, where $UU'T'U_z'U_z$ is the "unconstrained" envelope transformation surface from Figure II.10 and $UU'T'U_t'U_t$ is the relevant transformation surface following the elimination of pollution control method that was particularly effective on pollutants generated by industry y. Note that X-Y-Q combinations on $UTU'T'T$ lie on both transformation surfaces, while all combinations on $UTT'U_z'U_z$ dominate those on $UTT'U_t'U_t$. In this instance, by assumption, we illustrate a situation in which some particular policy constraint may or may not require a sacrifice of net output and/or environmental quality. Of course, other policy constraints that would definitely necessitate some sacrifice could be depicted in diagrams almost identical to Figure II.10.

Of course, the important conclusions to be drawn from this discussion are rather obvious (though not trivial) and simply stated. Technical efficiency in pollution control and the prevention of environmental degradation requires a diversified portfolio of pollution control and abatement policies, and constraints imposed on the selection of control and abatement policies may require society to sacrifice both output and environmental quality to achieve desirable political, social, or distributional objectives.

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[*] Since there are numerous different pollution control and abatement methods, the relevant transformation surface, $UU'U_z'U_z$, in Figure II.10 is drawn smooth and concave with respect to the origin. This seems reasonable, but where externalities and public goods exist, it is certainly conceivable that the relevant surface may be neither entirely smooth nor concave. Second-order conditions often are not satisfied in the presence of externalities and public goods. For an insightful discussion of these matters, see William J. Baumol, *Welfare and the State Revisited*, a new introduction to Welfare Economics and the Theory of the State, second edition (Cambridge, Mass.: Harvard University Press, 1965), pp. 3-8 and 32-36.

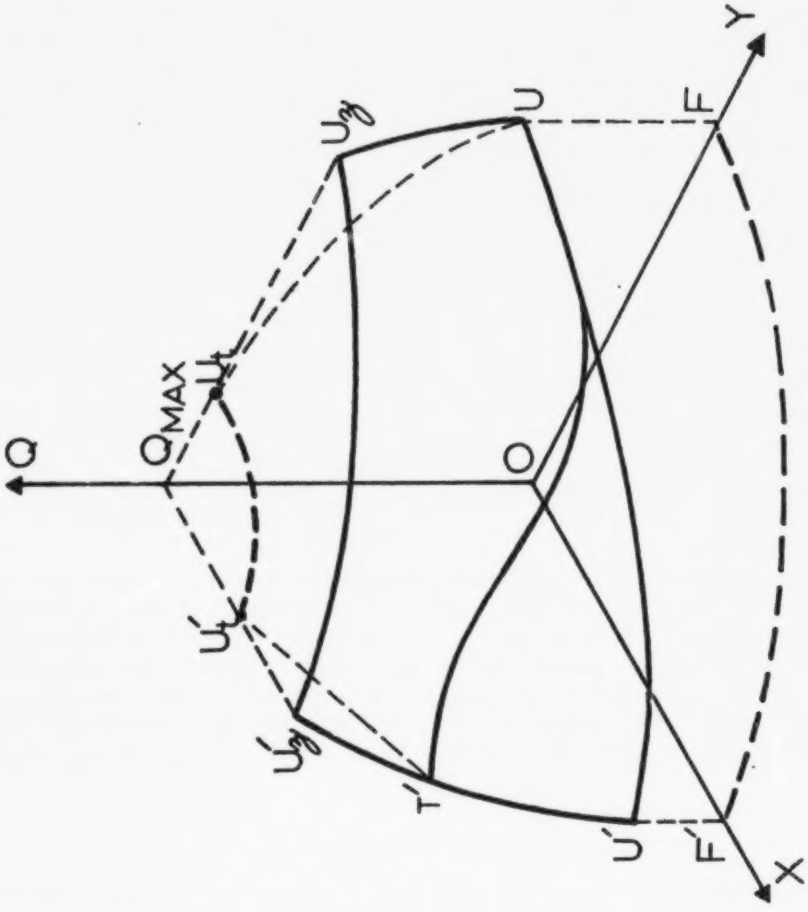
Q
$Q_{MAX}$
$U_1$
O
$U_1'$
$U_2'$
T'
U'
F'
X
$U_2$
U
F
Y

FIGURE II. 11

## C. Consumption Activities and Environmental Quality

We commence the specification of the consumption side of our model by defining the object of individual preferences to be "states of the world." Individuals are postulated to have the ability to rank alternative states of the world which differ in terms of (1) the consumption activities produced and consumed by individuals themselves and (2) the state of the environment, Q, experienced. In contrast to traditional microeconomic theory where individuals are assumed to have preferences defined in terms of the amounts of goods they alone consume, we more realistically assume that individuals' preferences extend beyond simply consumption activities to "things" which they experience in some aggregate sense individually and collectively, though not necessarily equally.

The building blocks of this specification are not original; they are due entirely to the brilliant insights of Becker and Bradford.* However, by specifying individual preferences to be an ordered function over alternative states of the world characterized by a set of consumption activities and some particular aggregate "thing" actually or potentially experienced by all individuals (e.g., air quality in the Willamette Valley), we have been able to extend the literature on the economics of air quality in two important respects. First, we have been able to derive testable hypotheses concerning which consumption activities would be negatively affected by deteriorating air quality and thereby avoid some of the intuitive empiricism that has characterized previous research. Secondly, we have been able to develop a methodology within which benefit-cost tests may be applied to evaluate alternative public policies to improve air quality. The remainder of this section indicates how these results follow from the above specification of individual preferences.

Put formally, we assume individuals have utility functions of the following form:

$$(10) \qquad U = U(Z_1, \ldots., Z_m; Q) \qquad Q \leq Q_{max}$$

where the Z's represent consumption activities and the utility function is continuous and quasi-concave. In contrast to traditional neoclassical consumer theory, the arguments in U are activities and the "state of the environment" (in some well-defined sense). Consumption activities are regarded as produced and consumed by individuals, and individuals by themselves control the scale on which each activity is undertaken. With respect to the state of the environment, however, individuals are viewed here as being unable to affect it by individual action alone.

In this framework, the individual is postulated to combine market goods, X and Y, and time in combinations that are technically defined to "produce"

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*The two major articles to which we refer are: Gary S. Becker, *A Theory of the Allocation of Time*, Economic Journal (September 1965); and David F. Bradford, *Benefit-Cost Analysis and Demand Curves for Public Goods*, Kyklos (September 1970).

particular consumption activities. In other words, there is a production function of the following sort for each activity

$$Z_j = F_j \, (X_j, Y_j; T_{1j}, \ldots, T_{hj}), \qquad j = 1,\ldots,m \tag{11}$$

where there are h different kinds of time which conceivably could be used to "produce" the j$^{th}$ consumption activity. Following the lead of Becker and Sorenson, we assume consumption technologies are linear and therefore rewrite the general production functions as

$$\begin{aligned} X_j &= a_j Z_j \\ Y_j &= b_j Z_j \\ T_{nj} &= t_{nj} Z_j \qquad\qquad n = 1, \ldots, h \end{aligned} \tag{12}$$

where $a_j$, $b_j$, and $t_n$; are fixed input-output coefficients.

Two features of this approach to consumer choice deserve special comment. First, consumption-activity production functions permit classification of activities according to their relative time and income intensities. This classification is a key element in Sorenson's derivation of testable hypotheses concerning the effects of changing air quality on consumption activities and expenditures. Second, and more obvious, demands for market goods, X and Y, are viewed here as derived demands which originate with individuals' selection among alternative potential consumption activities; and, therefore, demands for goods shift in response to changes in variables not usually investigated in empirical studies of consumer demand.

With matters of perspective and definition completed, we now turn to an analysis of the implications of our view of consumer choice. Once more following Sorenson, we postulate that in the selection of consumption activities individuals treat Q as a parameter and maximize their utility functions subject to their respective time and income constraints.* With Q viewed as a parameter, preferences are appropriately stated over consumption-activity space only. More precisely, we view the consumer's problem as a non-linear programming problem, which can be represented as follows:

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*In contrast to our view that changes in environmental variables shift tastes, it is appropriate to note that Becker has recently argued that the impact of environmental variables on consumer behavior can be best studied by introducing such variables into consumption activity production functions instead of through tastes. Becker argues that "this method of handling environmental variables is a powerful tool for greatly expanding the predictive content of economic theory." We disagree--at least in situations where the Becker model is applied to the study of air quality variations and consumption activity. The reason for our dissatisfaction with Becker's suggested is simple: neither Becker nor we are able to derive explicit testable hypotheses concerning shifts in consumers' production functions associated with air quality variations, whereas

Maximize:

$$U = U_Q(Z_1, \ldots, Z_m) \tag{13}$$

Subject to:

$$\sum_n \sum_j t_{nj} Z_j + \sum_s T_s = T \tag{14}$$

$$\sum_j c_j Z_j + \sum_s w_s T_s = G$$

$$Z_j \geq 0, \; T_s \geq 0$$

where $T_s$ = time worked in occupations,

$T$ = total time available,

$c_j$ = dollar cost per unit of market goods X and Y used in $Z_j$,

$w_s$ = the wage rate applicable in occupation s,

$G$ = "other" nonwage income, and

$U_Q$ indicates that the state of the environment is a parameter of the utility function relevant to the selection of optimal amounts of consumption activities.

Sorenson has investigated this programming problem in considerable detail. In particular, he has derived (1) the conditions that must be satisfied for an optimal solution (i.e., satisfaction-maximizing set of consumption activities) to this problem to exist and (2) the impact of parameter changes on optimal activity levels.

Unquestionably Sorenson's most important results are those obtained where he assumes that variations in the state of the environment (e.g. air quality) shift the utility function in a fashion such that

$$\frac{d}{dQ}\left(\frac{\partial U}{\partial Z_j}\right) \leq 0 ,$$

i.e., deterioration of the environment has negative or zero effects on the marginal utilities of activities. He concludes the discussion of this particular parameter change by deriving the testable hypothesis that relatively "income-intensive" consumption activities will be negatively affected by deteriorating environmental quality, where income- and time-intensiveness are defined in terms of the relative sizes of dollar expenditures per unit of time in the various consumption activities.

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*(continued from previous page) we have derived such hypotheses by postulating air quality variations affect consumer tastes. Consequently, although Becker's suggested method may prove useful in other contexts, we now doubt that its usefulness for air quality research.

For Becker's views on these matters, see Garry S. Becker, *Economic Theory* (New York: Alfred A. Knopf, Inc., 1971), pp. 47-48.

The Sorenson hypothesis concerning air quality and consumption activity suggests that air quality variations may well have considerably more extensive effects on consumption activity than previous research has revealed by examining intuitively obvious hypotheses (e.g., studies of soiling, corrosion, cleaning and painting expenditures, and so on) and finding rather meager and often uncertain effects. Although the Sorenson hypothesis proved useful for our research on seasonal air quality deterioration from open field burning in the Willamette Valley, perhaps the most useful test of the hypothesis would involve an intensive cross-section study of consumption expenditures, by income and social groups, across major U.S. metropolitan areas employing 1970 Census and other data. Until the results of a broad-scale investigation that tests well-specified hypotheses (e.g., the Sorenson hypothesis) concerning consumer activity and air quality are known, the real impact of air quality variations on consumer behavior must be regarded as only partially established by the existing body of research.*

We next turn to the development of an approach to the valuation of "the state of the environment" which permits (at least in principle) the application of benefit-cost tests to the evaluation of alternative public policies to improve air quality. We continue to postulate that the object of individual preferences are states of the world which may be characterized in terms of consumption activity and "the state of the environment." For expositional simplicity, however, we now assume that there is only one consumption activity, Z*. This assumption is merely a useful device for simplifying the derivation of the "total compensated demand function" which provides the foundation for our methodology of benefit measurement. Hence, we now write individual utility functions as follows:

$$(15) \qquad U = U(Z^*;Q) \qquad\qquad Q \leq Q_{max}$$

where Z* represents some (composite) index for private consumption activity, Q is defined as previously, and the utility function is again continuous and quasi-concave.

Our objective now is to show how information concerning individual preferences may be used to obtain benefit measurements for policies designed to change the state of the environment or a particular feature (say, air quality) of it. Since our view of what constitutes benefit-cost analysis perfectly coincides with that of Bradford:

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*The position taken in the text should not be interpreted as suggesting that most empirical investigations of "intuitively obvious" hypotheses would not have been undertaken had the Sorenson hypothesis guided research design. Quite the contrary, many of the "obvious" hypotheses are consistent with the Sorenson hypothesis. For example, since housing expenditures are clearly income-intensive, research on housing decisions, land values, etc., and variations in air quality would rank high on a research agenda determined strictly by the Sorenson hypothesis.

> Benefit-cost analysis can be...described as a technique to discover whether a proposed change in one variable of the state description can be feasibly obtained by changes in other variables such that the new state is preferred by some citizens, the existing state preferred by none. More simply but less precisely put, it is a procedure for testing the Pareto optimality of the existing state. The general approach is to seek to determine the maximum amount citizens would be willing to pay for some change, and the minimum amount that must be given up to obtain it. If the former, the aggregate benefits, exceeds the latter, the cost of the change, it is the usual view that the change should probably be undertaken.*

We now suggest a method for measuring the "maximum amount citizens would be willing to pay for some change." Before doing this, however, it is appropriate to state explicitly that neither Bradford nor we claim that a benefit-cost test of the sort described here is sufficient by itself to determine whether a specified change "should" be undertaken. We agree with Bradford that answers to this and similar normative questions can only be determined by introducing a well-defined social welfare function and a specification of the available alternatives.**

In keeping with traditional consumer behavior theory, we assume that individuals have the ability to rank all alternative states of the world in order of preference. It is further assumed that individuals are indifferent between states identical in terms of their own consumption activity and the state of the environment, even if the distribution of consumption activity among other individuals differs in these states. Without this latter assumption, benefit-cost analysis of the standard sort is quite impossible, particularly for large changes in the state of the world. The reason for this is clear. Each individual's willingness to pay for some change would itself change as other individuals' contributions varied, and therefore benefit estimates derived from the market or pseudo-market data normally employed in benefit-cost analysis would be quite inadequate to characterize the range of aggregate willingness-to-pay figures that are likely to obtain.

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*David F. Bradford, op.cit., pp. 787.

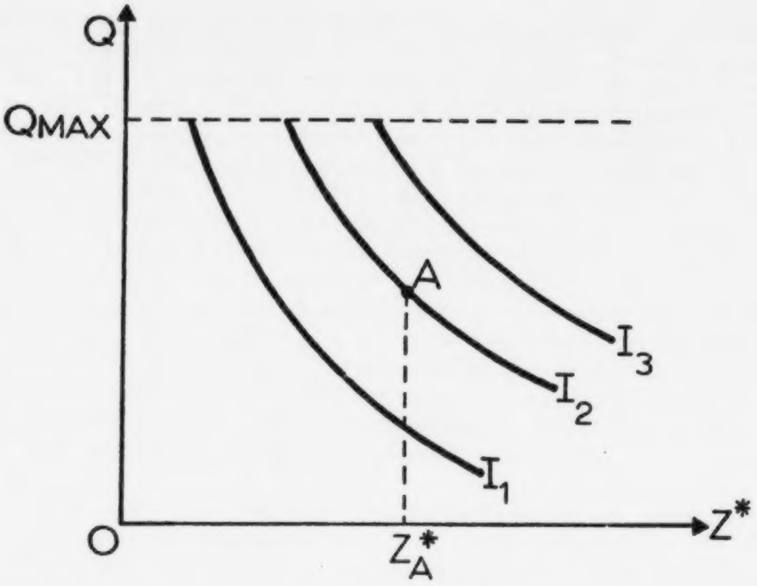
**For compelling arguments in support of this position, see David F. Bradford, *Constraints on Public Action and Rules for Social Decision,* American Economic Review (September 1970).

Given our assumptions, Figure II. 12 depicts the indifference map of what we presume to be a typical individual. Each indifference curve indicates alternative equally-preferred states of the world, and successively higher curves indicate increasingly preferred states. Note that the indifference map extends only over the conceivably feasible state-of-the-world space.

If the initial state of the world was such that our typical individual found himself at point A in Figure II. 12, what would be the maximum amount of consumption activity that the individual would be willing to forego for various changes in the state of the environment? The answer to this question is provided in Figure II. 13, where the curve AOA′ is indifference curve $I_2$ drawn with new axes to establish a new origin, O′. Given AO′A′, the new horizontal axis $\Delta Z^*$ permits measurement of the maximum amount that the individual would be willing to forego to secure different environmental states, given his initial state at point A in Figure II. 12. Since the slope of AO′A′ is the marginal rate of substitution of $Z^*$ for Q along $I_2$, AO′A′ is the "total" compensated demand curve associated with the usual compensated demand curve. Of course, an aggregate "total" compensated demand curve for different states of the environment would be constructed by the "vertical" addition of all individual "total" compensated demand curves.

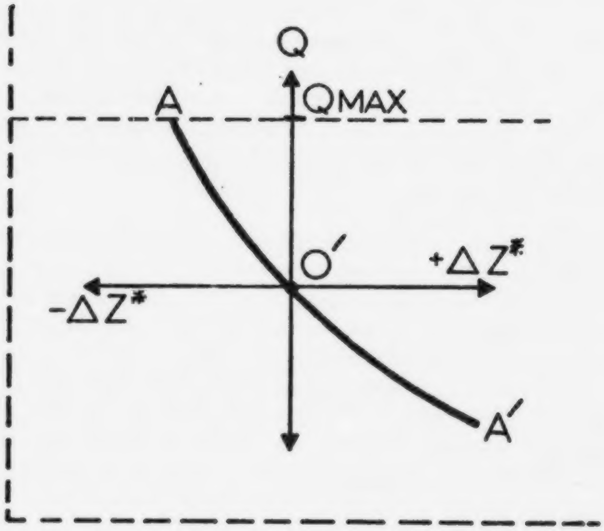
Since the properties of such aggregate "total" compensated demand functions are unusual, they are worthy of further discussion. First, by construction, at any point on the aggregate curve all individuals remain on their initial-state indifference curves; no one's welfare has either increased or decreased. Second, in contrast to the situations described by the usual compensated or uncompensated demand function for a private good, individuals would not generally have identical marginal rates of substitution between the numeraire (here, $Z^*$) and the state of the environment at each point along the aggregate "total" compensated demand function. We do not presume that individuals have identical tastes for environmental quality. Third, by construction, the slope at any point of an aggregate "total" compensated demand function is the sum of individual marginal rates of substitution given that every individual remains on their initial-state indifference curve. Consequently, an aggregate "total" compensated demand function provides a measure of both total and marginal benefits of each environmental state (given the initial state) in precisely the fashion that an ideal benefit-cost analysis would require.

On the basis of the preceding analysis, we conclude that there is little conceptual difficulty in the application of benefit-cost analytical techniques to the evaluation of projects and policies designed to change the state of the environment. On the other hand, however, there are obviously formidable estimation and measurement questions that must be addressed in any particular application. Some of these matters are discussed in the following section where the production and consumption sides of our suggested framework are brought together.



Q
QMAX
A
$I_3$
$I_2$
$I_1$
O
$Z^*_A$
$Z^*$

FIGURE II. 12



Q
A
QMAX
O′
+ΔZ*
-ΔZ*
A′

FIGURE II. 13

## D. Benefit-Cost Analysis Of Environmental Quality

Benefit-cost analysis has been described earlier "as a technique to discover when a proposed change in one variable of the state description can be feasibly obtained by changes in other variables such that the new state is preferred by some citizens, the existing state preferred by none." To put this view slightly differently, benefit-cost analysis is a branch of applied welfare economics founded on the potential Pareto improvement principle. A potential Pareto improvement may be defined as an economic rearrangement in which the gainers could more than compensate the losers, assuming redistributions to be costless. However, the fact that some specified economic change passes a benefit-cost test is not sufficient to determine whether the change should be made. In general, where one discovers one potential Pareto improvement, it is rarely difficult to find others as well, and selection among alternative feasible potential Pareto improvements requires introduction of a social welfare function. Consequently, at best benefit-cost calculations provide useful, though hardly conclusive, comparative information for assessing the desirability of alternative feasible projects, programs, or policies.

As the preceding paragraph indicates, we claim less for benefit-cost analysis than is often the case. Nevertheless, we believe that assessment of alternative public policies to change the state of the environment (a public good) by application of the potential-Pareto-improvement criterion is feasible, both on the conceptual level and in practice. In this section, we begin our demonstration of how benefit-cost analysis can usefully be applied where public and private goods matter to individuals. We do this by bringing together the production and consumption sides of our framework to specify the adequacy and comprehensiveness of benefit-cost tests of alternative pollution control methods and policies. Following completion of this task, we report the application of the conceptual approach developed here to assess the benefits and costs of various public policies to control pollution from open field burning in the Willamette Valley.

To determine whether potential-Pareto-improvements exist (i.e., whether any feasible policies have benefit-cost ratios greater than unity), the analyst must confront the aggregate "total" compensated demand function with the envelope transformation surface relevant for pollution control policy selection. This is accomplished here with the aid of Figure II. 14, where in panel (a) the relevant transformation surface, $UU'U_Z'U_Z$, is superimposed on two alternative representations of the aggregate derived "total" compensated demand surface associated with the assumed initial state at point G.* Panel (b) of Figure II.14 provides a cross-section view of panel (a),

---

*Since our analytical results would apparently be more easily understood if obtained in final-goods-environmental-quality space than in consumption-activity-environmental-quality space, we henceforth refer to aggregate "total" compensated demand functions or surfaces as relevant derived demand functions or surfaces. Although this terminology is intended to remind the reader that we regard consumption activities, not final goods, as arguments in individual utility functions, it is important to note that the transition from activity-

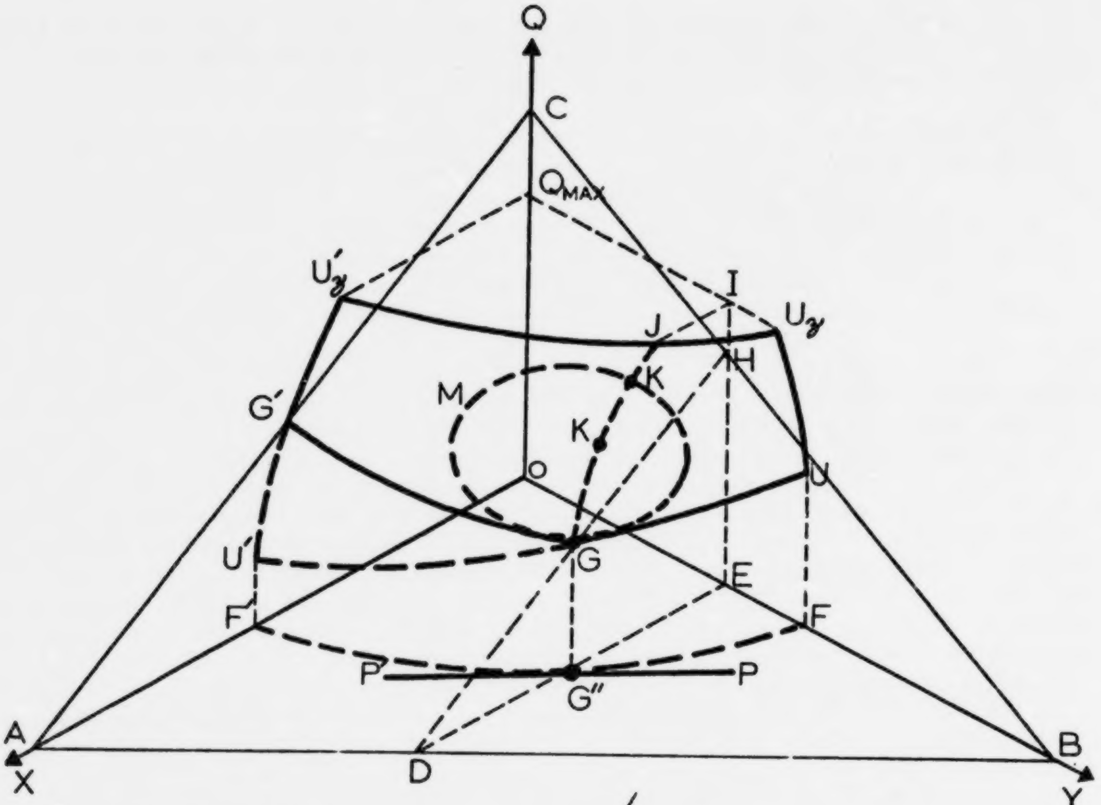

Q
C
$Q_{MAX}$
$U_y'$
I
$U_y$
J
H
K
M
G'
K
o
U
U'
G
E
F'
F
P
P
G''
A
X
D
B
Y

FIGURE II. 14(a)

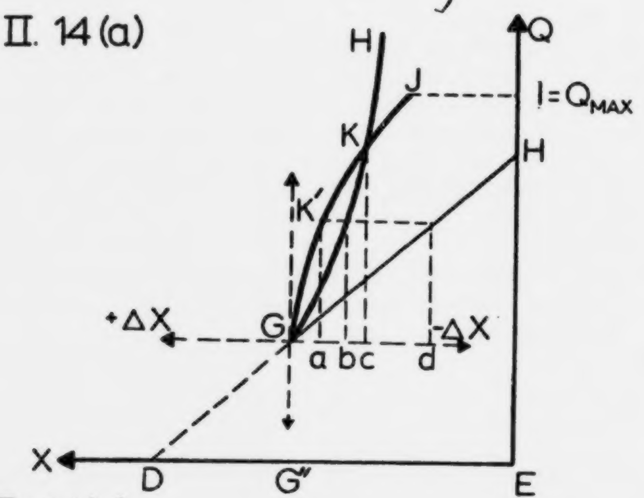

H
J
Q
$I = Q_{MAX}$
K
H
K'
+ΔX
G
-ΔX
a
b
c
d
X
D
G''
E

FIGURE II. 14(b)

where G serves as the origin for the superimposed axes for two cross-sections, GH, GH´ and GK´KJ, of the two relevant derived demand surfaces and the relevant transformation surface, respectively.

Based on earlier discussion and appendix A, we postulate that at G the economy is in full competitive equilibrium with no pollution control policies. At G, final good outputs are OE units of Y and EG´´ units of X, relative final good prices are indicated by the slope of PP´ which is tangent to FF´ at G´´, and the state of the environment is G´´G on an index with $OQ_{max}$ as its maximum value. (Information concerning the income distribution at G can be derived in the fashion described in appendix A.)

With these preliminary matters completed, we now indicate how benefit-cost analysis may contribute to the selection among potential pollution control policies. If the relevant derived demand surface associated with the initial state, G, is known to be tangent to the plane ABC in panel (a) of Figure II. 14, the initial state is technologically efficient (because the economy is operating on its transformation surface) but potential Pareto improvements are available for exploitation. Suppose the relevant derived demand surface at G is known (1) to be convex with respect to the origin and (2) to trace the elipze GMK as it passes through the relevant transformation surface, $UU_z'U'U_z$. In fact, all pollution control policies (individually or in combination) that would place the economy on or in the space contained between the relevant demand and transformation surfaces would result in potential Pareto improvements in the initial state, and all policies falling within this set would have benefit-cost ratios greater than or equal to unity.

The preceding conclusion and its relation to standard benefit-cost analysis can be more readily appreciated with the aid of panel (b) to Figure II. 14. With a given final output of OE units of Y, all policies that would move the economy to points on or within the space between the cross sections of the relevant derived demand and transformation curves, GH´ and GJ, respectively, would have measured benefits equal to or exceeding their costs. For example, adoption of a set of policies placing the economy at K´ would have measured benefits, Gb, measured costs, Ga, and a benefit-cost ratio, Gb/Ga, clearly exceeding unity. In contrast, the set of policies moving the economy to K would only have a benefit-cost ratio, Gc/Gc, equal to one. Consequently, all technologically efficient policies constrained by the relevant derived demand surface must necessarily have benefit-cost ratios which exceed or equal one.

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*(continued from previous page) to goods-space means that the assumed quasi-convexity of individual utility functions is not sufficient to establish the convexity of the relevant derived demand surface. Fortunately, however, none of our principal analytical results depend on the convexity of the relevant derived demand surface.

Unfortunately, however, the preceding result for technologically efficient policies appears stronger than in fact it is. To refer to panel (b) of Figure II. 14 once again, all policies moving the economy to positions *within* the space constrained by the relevant derived demand and transformation curves would also have benefit-cost ratios exceeding unity. For this reason, benefit-cost ratios greater than one *must not* be viewed as synonymous with technologically efficient projects or policies, and the standard benefit-cost study should always be supplemented with cost-effectiveness investigations designed to assure selection among technically efficient (i.e., dominant) policies.

Similar cautionary remarks are also appropriate here concerning the impropriety of selecting the technologically efficient policy with the highest benefit-cost ratio (or alternately, the greatest net benefits). To apply these criteria would mean the selection of policy by maximizing some index of the *potential* gains from trading the existing state for some new state. However, since benefits are defined as the maximum amount individuals are willing to pay for some specified change in the existing state, while costs are defined as the minimum amount that must be foregone to obtain the change, the potential gains reflect individuals own valuations of alternative states given the existing distribution of income and wealth. Consequently, selection of the policy with the highest benefit-cost ratio, or greatest net benefits, is appropriate only if the social welfare function has relative weights *identical* to individuals' relative valuations in the existing *non-optimal* state. If the social welfare function has any other set of relative weights, welfare maximization is incompatible with selection of the policy having the highest benefit-cost ratio, or greatest net benefits, as these are measured in the standard benefit-cost analysis.

Although the preceding remarks emphasize that benefit-cost analysis by itself cannot determine the "best" project or policy for society to undertake, they are not intended to minimize the potential usefulness of standard benefit-cost analysis. On the contrary, they are intended only to prevent possible misuse of benefit-cost evaluations by indicating precisely what a benefit-cost ratio greater than one does or does not reveal. Moreover, perhaps the most useful feature of benefit-cost evaluations of alternative policies is their ability to identify policies which would not be Pareto improvements over the existing situation, thereby assisting the specification of the set of alternative policies which are properly investigated in great detail to determine the policy subset that would maximize social welfare. Thus, negative results often indicate the direction that policy should change to achieve genuine gains for society.

This position can be illustrated with the aid of Figure II. 14, panel (a). There, as we have previously observed, if the relevant derived demand surface associated with the initial state at G traces the elipse GMK as it passes through the relevant transformation surface $UU'U'_zU_z$, all technologically efficient policies that would move the economy from G to points outside the elipse on $UU'U'_zU_z$ would have benefit-cost ratios less than one. A similar, though perhaps less useful, partition of the set of technologically efficient policies can also be achieved by benefit-cost analysis without full knowledge of the relevant derived demand function. Where the analyst (a) knows individuals' valuations in the initial state and (b) makes "reasonable" assumptions concerning the properties of the unknown demand function, benefit-cost calculations can be undertaken and the policy set partitioned as described above. For example, suppose the analyst knows that the relevant derived demand function is tangent at G to the plane ABC in Figure II. 14, panel (a), and assumes that the valuations implicit in the slopes of the plane ABC at G are "reasonable" for calculation of the benefits of alternative policies. By this procedure, policies associated with area $GU'G'$ on the relevant transformation surface would be found to have benefit-cost ratios less than one, whereas policies associated with area $UGG'U_z'U_z$ would have benefit-cost ratios greater than one. Therefore even without full knowledge, reasonable applications of benefit-cost methodology would appear to generate useful results for social decision-makers.

Finally, we should note that if the initial state is itself Pareto optimal, the relevant derived demand surface never lies below the relevant transformation surface.* In such circumstances, all policies changing the initial state would have benefit-cost ratios less than one. For this reason, benefit-cost analysis is properly regarded as a means for testing the Pareto optimality of the existing (or some initial) state. Of course, where Pareto optimality obtains, all of the usual necessary marginal conditions also hold; for example, the sum of individual marginal rates of substitution of private goods for environmental quality would equal the marginal cost of environmental quality improvement.

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*It should be recalled that the relevant demand curve always refers to changes in some particular initial state and would be different at each conceivable state. Furthermore, it should be noted that the proposition stated in the text does not rule out either corner solutions or multiple Pareto optimal situations. Such situations cannot be excluded as possibilities because the relevant derived demand function is not necessarily convex.

# III. THE COSTS OF ALTERNATIVE OPEN FIELD BURNING CONTROL POLICIES

## A. Introduction

In contrast to the majority of studies concerned with air pollution control costs, the investigation reported here must focus on the effects of control regulations on a major segment of a competitive industry. To do this, we employ statistically estimated supply and demand functions for the major types of grass seed raised in the Willamette Valley to predict how prices, outputs, etc. would change following the introduction of, and industry adjustment to, alternative field burning control policies. These results are then used to calculate the policy-induced changes in consumers' surpluses, rents to specialized factors, etc. in the grass seed industry. Although not all of the changes we predict and report here are costs in the sense that they measure the value of goods and services foregone by society as a result of Oregon's open field burning control policies, each change does measure the impact of policies on groups potentially important in public policy formation.

Although our methodological approach is quite standard in most respects, our basic model, measurement techniques, and level of disaggregation distinguish the estimates reported here from those made in other studies with similar methodological approaches. To be specific, our adoption of standard partial-equilibrium methodology has not precluded prediction and measurement of the very different effects of Oregon control policies on seed producers located inside and outside Oregon or owners of Willamette Valley land presently in seed production. Furthermore, for what we believe is the first time, we do not measure changes in producers well-being by changes in the areas above the statistical supply curves employed to predict post-control prices and outputs. This separation of prediction and measurement means that our estimates of changes in producers well-being are probably more realistic than those sometimes reported in other studies.

The next section presents the analytical framework and measurement techniques employed here to estimate the costs associated with three alternative policies regulating open field burning in Oregon. Section C presents our actual estimates of the changes in consumers' surpluses and producers' rents associated with the three policies, while section D translates the predicted reductions in Oregon rents to decreases in the value of Willamette Valley agricultural land presently in grass seed production.

## B. An Analytical Framework for Measuring the Costs of Regulating Open Field Burning

The concepts of consumers' and producers' surpluses have often been employed to evaluate the effects of resource misallocation, gains and losses from international trade, price instability, and public and private investments.*

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*For an excellent recent survey of the literature on consumers' and producers' surplus, see J. M. Currie, J. A. Murphy, and A. Schmitz, *The Concept of Economic Surplus and its Use in Economic Analysis*, Economic Journal, Vol. 81 (December 1971), pp. 741-799.

The basic model used to evaluate the welfare effects of investments is depicted in Figure III.1, which is identical to the figure that Schmitz and Seckler present to explain their method of computing the rate of return on investment in the development of the mechanized tomato harvester.* We repeat the Schmitz-Seckler figure for two reasons: (1) it conveniently initiates illustration of the basic concepts used here to measure some effects of regulating open field burning int he Willamette Valley; and (2) it also illustrates why "obvious" procedures for measuring producers' surplus may result in unrealistic estimates clearly inconsistent with basic microeconomic theory. Following this discussion of definitional and methodological matters, we specify the particular model and estimation procedures employed in this report.

Following Schmitz and Seckler, suppose that some technological improvement reduces production costs, thereby shifting the supply curve in Figure III.1 from $S_0$ to $S_0$ following adoption of the technique throughout the industry. The gain in consumers' surplus is measured as the area E + G + F, while the gain in producers' surplus is H + I - E. However, if the initial supply curve had been perfectly elastic, the only gain to society would be the gain in consumers' surplus E + G + F since producers' surplus does not exist. Schmitz and Seckler define the sum of producers' and consumers' surpluses to be the gross social gain from the postulated technological change. They also go one step further than previous researchers and calculate the net social gain to society. They define the net social gain to be the gross social gain minus the aggregate wages that would have been paid to workers displaced by the innovation.

Although each of these measures has been the subject of much criticism, they do provide rough estimates of magnitudes that are properly regarded as important in the appraisal of major public and private investments. In any case, "while it is easy to raise objections to the use of the concept of economic surplus for providing answers for policy formulation, it is difficult to find any workable alternatives."**

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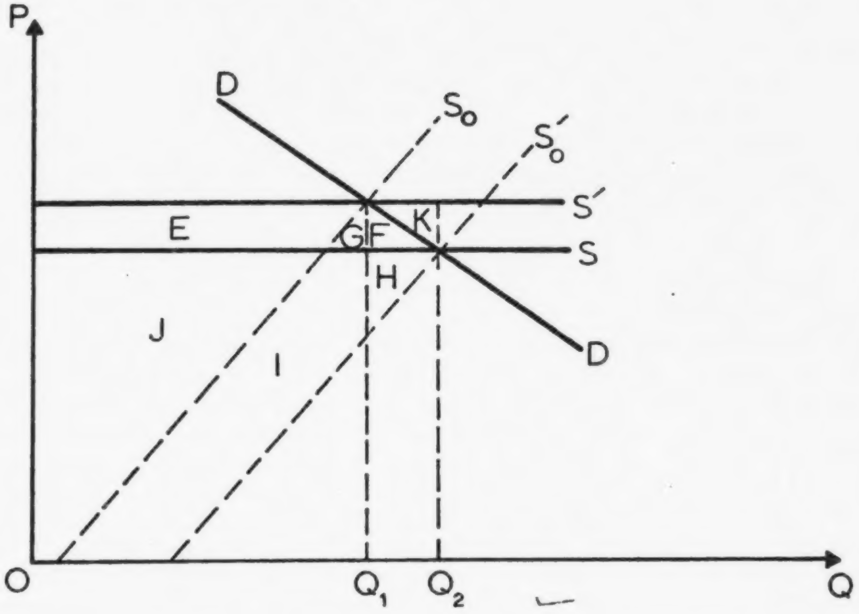
*A. Schmitz and D. Seckler, *Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester,* American Journal of Agricultural Economics, Vol. 52 (November 1970), pp. 569-580.

**J. M. Currie, et al., op. cit., p. 791. The first section of this article (pp. 742-765) provides a careful, balanced exposition of the major theoretical contributions to the development of the concepts of consumers' and producers' surplus, including full treatment of the objections to the concepts.


P
D
$S_o$
$S_o'$
S'
E
G
F
K
S
H
J
I
D
O
$Q_1$
$Q_2$
Q

GAIN IN CONSUMER'S SURPLUS = E + G + F
GAIN IN PRODUCER'S SURPLUS = H + I + E

FIGURE III. 1

As indicated by the definition given above, the traditional measure of producers' surplus is the area above the supply curve and below the price line. Consequently, what this area actually measures depends on the nature of the supply curve postulated. By addressing ourselves to this question to determine how to define producers' surplus in the Oregon grass seed industry, we discovered a significant error was made in the construction of Figure III.1 by Schmitz and Seckler. (We had previously uncovered the same type of error had been made in an empirical study of externalities in the farm use of pesticides by Edwards.)* In Figure III.1, both $S_o$ and $S_o'$ intersect the horizontal axis, thereby implying that producers' surplus at low levels of output equals price. Although there has been considerable controversy what supply curve to employ to measure producers' surplus, economic theorists as a group would generally agree that short- and long-run marginal production costs, including or excluding rents, are zero only in very rare circumstances. Therefore, Figure III.1 must be regarded as constructed in a theoretically unjustifiable fashion.

This finding led us to reconsider previous definitions and measurements of producer's surplus. With respect to measurement of producers' surplus, we conclude that econometric supply functions are unrealistic tools to employ for two very practical reasons. First, econometrically estimated supply functions often have either positive horizontal axis intercepts implying zero marginal costs at low output levels or positive vertical-axis intercepts substantially different reasonable estimates of long-run marginal costs excluding all quasi-rents to variable factors. Second, even if vertical-axis intercepts were forced to approximate marginal costs, there is no necessary correspondence between the slope and degree of curvature of the estimated and desired supply function. Moreover, with respect to the desired supply function itself, we found ultimately that we agreed with Mishan that (1) the area above the supply curve is comparable to consumers' surplus only under special circumstances in the short-run and (2) the concept of economic rent is "perfectly symmetric" with the concept of consumers' surplus.** Therefore, to avoid confusion and to follow Mishan's lead, we henceforth dispense with the term producers' surplus and instead refer to "aggregate industry rents."

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[*] See W. F. Edwards, *Economic Externalities in the Agricultural Use of Pesticides and an Evaluation of Alternative Policies,* unpublished Ph.D. Thesis, University of Florida, 1969. Edwards employs linear supply-response functions derived from his econometric study of vegetable and fruit supply functions in Dade County, Florida to calculate producers' surplus; some of his supply functions have positive horizontal-axis intercepts. Edwards makes his error without constructing a theoretically unrealistic figure, however.

In contrast to Edwards, Schmitz and Seckler construct a theoretically unrealistic figure to define producers' surplus, but they do not calculate a measure of producers' surplus in their article.

[**] E. J. Mishan, *What is Producer's Surplus,* American Economic Review, Vol. 58, No. 5 (December 1968), pp. 1269-82, especially pp. 1271-73 and 1278-79.

Aggregate industry rents are defined here as aggregate industry returns to those factors of production typically regarded as perfectly or highly inelastic in supply to the industry in the short-run. Industry aggregate rent per unit of output equals output price minus median or mean average variable costs in the industry, and industry aggregate rents are measured as the product of industry aggregate rent per unit of output and industry output. The word aggregate appears in our definition because we attempt to measure the sum of returns to all commonly regarded fixed and/or highly specialized factors of production. Here, changes in aggregate industry rents replace changes in producers' surplus as an empirical measure of the welfare (here, income) changes experienced by owners of specialized factors.

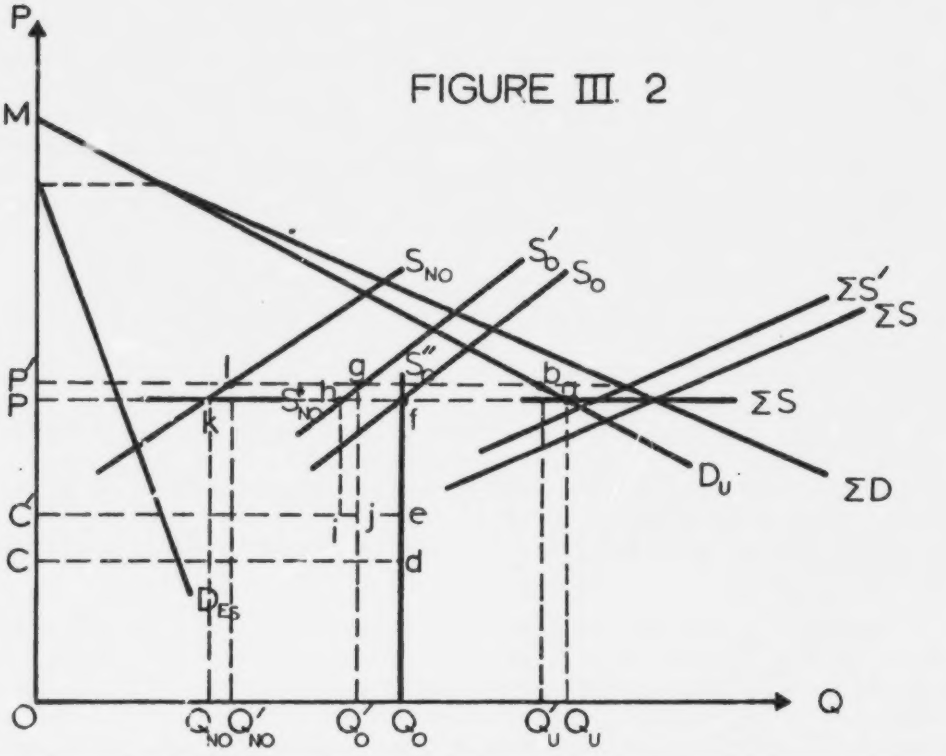
Of course, in absolute terms it is clear that this procedure does not provide an accurate measure of rents as they are traditionally defined. There are at least two reasons for this. First, quasi-rents received by variable factors are excluded from our measure. Second, the non-pecuniary advantages of particular employments and occupations would only rarely equal the total payment received by the owners of land, specialized facilities, equipment, entreprenuerial ability, etc. In any case, although we are disappointed to work with an absolutely inaccurate measure of aggregate industry rents, we do not regard the inaccuracy as fatal given our objective of obtaining a reasonable measure of the change in rents consequent to the introduction of various pollution control policies.

Traditional partial equilibrium reasoning underlies the preceding conclusion. If some subset of the normally regarded "fixed" factors are truly specialized to a pollution-policy affected industry, then any decline in aggregate industry rents as defined here would necessarily be entirely borne by those specialized factors. Moreover, if some "fixed" factors do leave the policy-affected industry, those which remain because they lack employment opportunities elsewhere must also bear the entire change in aggregate industry rents as defined here. Consequently, an ability to measure changes in aggregate industry rents as defined here is equivalent to an ability to measure the change in returns to an industry's "specialized" factors.

In the next section, we present alternative estimates at farm level of the losses in consumers' surplus and rents to Oregon seed producers, as well as the gain in rents to non-Oregon seed producers, that would result following implementation of, and industry adjustment to, three alternative policies regulating open burning of Oregon seed fields. The basic model used to make these estimates is illustrated in Figure III.2; the table below the figure indicates the areas measured to compute the losses and gains experienced by the three groups affected by the policies investigated. As the table shows, alternative assumptions concerning relevant supply elasticities greatly influence the size of gains and losses experienced by the affected parties. In Figure III.2, Oc measures mean average variable costs for Oregon producers prior to the introduction of open field burning regulations, while Oc'measures mean average variable costs after introduction of field burning regulations. As the areas in the table imply, OP, OQO, and $OQ_{NO}$ represent the pre-regulation price, Oregon output, and non-Oregon output respectively.

The final section in this part of the report translates the rent losses to Oregon seed producers into decreases in the value of Willamette Valley agricultural land presently in grass seed production. The basic model used to obtain

FIGURE III. 2


P
M
$P'$
P
$C'$
C
O
Q
$S_{NO}$
$S_o'$
$S_o$
$\Sigma S'$
$\Sigma S$
$\Sigma S$
$\Sigma D$
$D_U$
$D_{ES}$
$S^*_{NO}$
$S_o''$
l
k
g
h
f
b
a
i
j
e
d
$Q_{NO}$
$Q_{NO}'$
$Q_o'$
$Q_o$
$Q_U'$
$Q_U$

| Gain or Loss, by Oregon Supply Situation | Alternative Non-Oregon Supply Situation | |
|---|---|---|
| | $S_{NO}$ | $S^*_{NO}$ |
| Loss in Consumer's Surplus, | | |
| $S_o'$ | PabP′ | 0 |
| $S_o''$ | 0 | 0 |
| Loss in Oregon Rents, | | |
| $S_o'$ | Pcdf-P′c′jg | Pcdf-Pc′ih |
| $S_o''$ | cdec′ | cdec′ |
| Gain in Non-Oregon Rents, | | |
| $S_o'$ | PklP′ | 0 |
| $S_o''$ | 0 | 0 |

these losses may be illustrated with the aid of Figure III.3. This model postulates that policies restricting open field burning would result in a leftward shift in the demand for land to raise grass seeds from $D_s$ to $D'_s$ and lower the price of seed land at the margin from OP to OP'.

Since the marginal land presently in seed production has other potential agricultural and/or non-agricultural uses, we do not postulate a model in which the supply of land for raising grass seeds is perfectly inelastic. To emphasize this point, panel (b) of Figure III.3 was consturcted to represent the demand curves in panel (a) to demonstrate that demand curve for land in other uses than seed production, $D_{OU}$, may also be interpreted as the supply curve of seed land.* For this reason, the demands for land in other uses have an important influence on the impact of open field burning control policies on agricultural land values. Explicit attention is given these matters below.

## C. Changes in Consumers' Surpluses and Producers' Rents Under Alternative Open Field Burning Control Policies

This section reports and discusses our estimates of the absolute and relative changes in consumers' surpluses and producers' (Oregon and non-Oregon) rents associated with three alternative open field burning control policies. The effects of each policy are estimated assuming three rather different supply situations in order to indicate the full range of possible outcomes. This procedure seemed advisable because Oregon dominates U.S. production of certain seed crops, and information concerning non-Oregon grass-seed supply functions is very limited. Referring to Figure III.2 once again, the three supply situations are:

I. Normal Supply Situation: positively-sloped supply curves, $S_o$ and $S_{NO}$;

II. Polar Supply Situation (1): perfectly inelastic Oregon supply curve, SO , reflecting limited alternatives available to Willamette Valley producers, and $S_{NO}$; and

III. Polar Supply Situation (2): perfectly elastic non-Oregon supply curve, $S^*_{NO}$, and normal Oregon supply curve, SO (This situation is unrealistic but allows to establish the maximum potential loss in Oregon rents.)

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*Panel (b) of Figure III.3 is constructed in a fashion similar to the one used by Stigler to analyze the price determination of storeable goods with fixed supplies. See George J. Stigler, *The Theory of Price*, 3rd ed. (New York: The Macmillan Company, 1966), pp. 96-98.

Of course, the reduction in air pollution associated with the control policies may increase demands for land in other uses because the attractiveness of the Valley to potential residents and foot-loose firms increases. Although we recognize this possibility, we doubt that it is important in the present case.

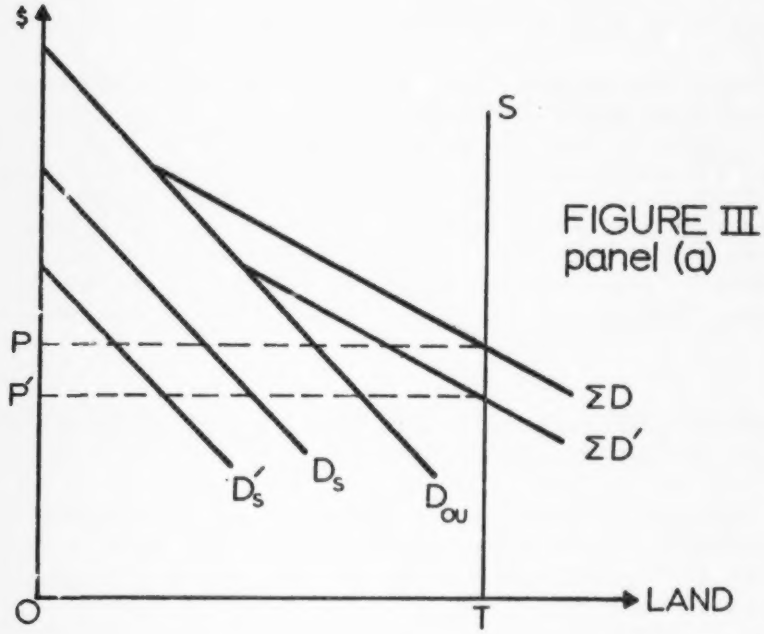

FIGURE III. 3
panel (a)

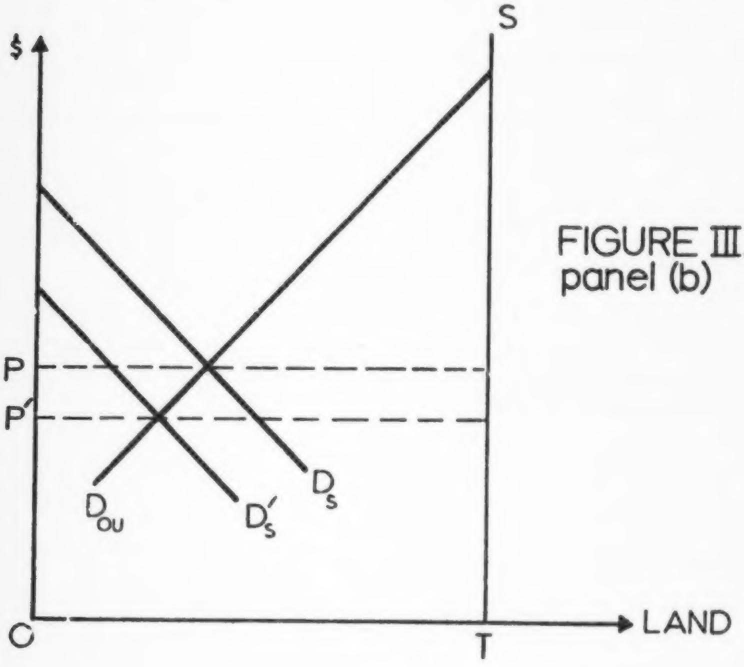

FIGURE III. 3
panel (b)

The three field burning control policies investigated here are:

A. A complete ban on open burning;

B. Open burning permitted once in three years; and

C. Alternate year burning.

These policies would reduce total acres burned per season by 100, 67, and 50 percent, respectively, and each would improve visibility in the Willamette Valley to a different degree.

Each of the above policies, however, would increase grass seed production costs regardless of how individual operators adjust their cultivation, harvest residue removal, and disease control practices.* Tables I.3 and I.4 supply substantial evidence that partial or complete elimination of open field burning would increase total costs per acre and/or simultaneously reduce yields per acre. Moreover, in the absence of burning there would probably be increases in the incidence of seed diseases, decreases in seed purity, and increases in seed cleaning costs. These last problems would not exist if mobile field sanitizers were used to replace open field burning, entirely under policy A and partly under policies B and C. Fortunately, it now (June 1972) appears that an effective mobile field sanitizer may be able to operate at a cost as low as $5 per acre, though $9 per acre is regarded as today's best estimate of its cost. Since controlled burning with the sanitizer appears to produce the same beneficial residue disposal and cultivation effects as open burning without producing smoke which reduces visibility, the sanitizer must now be viewed as the low-cost alternative to open field burning. Therefore, we estimate the changes in consumers' surpluses and producers' rents under our three alternative control policies assuming Oregon producers adopt the mobile field sanitizer and incur costs equal alternately to $5, 9 and 13 per acre in the years they do not burn.**

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*Here we make the usual assumption that overall efficiency (or, for that matter, inefficiency) in the Oregon grass seed industry is not affected by the "pressure" that various pollution control policies would place on the industry. Since such policies would undoubtedly induce rationalization of industry organization, our estimates of declines in producers' rents would be expected to exceed observed losses.

**We employ these cost figures at the suggestion of Professor Frank S. Conklin, who has expended considerable effort attempting to develop realistic cost estimates for the sanitizer.

We should also note that our estimates assume that the sanitizer has no effect on yields per acre. Professor David Chilcote informs us there is limited evidence that the sanitizer may conceivably increase yields by producing more uniform burning than can be accomplished with the open burning technique. If further research establishes this to be true, our estimates of declines in producers' rents would necessarily exceed actual losses.

Appendix F reports the statistical investigation of grass seed demand and supply functions that underlie our predictions of the effects of alternative field burning control policies. There we derive the linear supply and demand equations employed to compute the estimates of policy-induced changes presented in Tables III.1 and III.2. Those equations, and hence our estimates of surplus and rent changes, are based on 1965-69 average prices and quantities at the farm level. Therefore, our surplus and rent estimates attempt to measure what changes would have occurred if the grass seed industry had adjusted to the open field burning control policies in the late sixties.*

The estimates presented in Tables III.1 and III.2 suggest the following observations. (1) Except in the case of red fescue, the declines in Oregon rents under each policy are approximately the same in supply situations I and II. This result is important because supply situation I assumes "normal" reactions by Oregon producers to the policy-induced cost increases, whereas supply situation II assumed that Oregon producers are "boxed in" to seed production because of the special climactic, soil, and market conditions they face. Interestingly, the resulting losses for the industry appear to be about the same in either situation. (2) On the other hand, the declines in Oregon producer rents in supply situations I and II are only 50-75 percent of the losses we estimate they would suffer in supply situation III. Consequently, to the extent that non-Oregon supplies are substantially more responsive to price than we assumed in supply situation I, the decline in Oregon rents could potentially exceed our "most reasonable" estimates by perhaps 20 to 50 percent.**

(3) Except in the case of tall fescue, the absolute decrease in consumers' surplus is less than the decrease in Oregon producers' aggregate rents in supply situation I. This difference is most dramatic in the case of ryegrass. By the same token, it should be immediately noted that the relative decrease in consumers' surpluses for ryegrass is slightly greater than the relative in Oregon producer rents. For all other seeds, however, the relative decrease in consumers' surpluses is also smaller than the relative decrease in Oregon rents. (4) Of course, the principal reason for these results is that non-Oregon producers would expand their outputs as Oregon producers react to introduction of the more costly production methods associated with alternative open field burning control policies. It is interesting to observe in Table III.2 that the relative increase in non-Oregon producer rents exceeds the relative decrease in Oregon rents for tall fescue, red fescue, chewings fescue, and bentgrass.

(5) Finally, we note that the assumed linearity in our demand and supply funtions does result in absolute or relative changes in consumers' surpluses and producers' rents that are proportional to the postulated changes in costs. Although this result is not particularly unusual, it does indicate the potential errors associated with common extrapolative procedures.

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*Tables III.1 and III.2 report only changes in consumers' surpluses and producers' rents. See Appendix G for tables which report predicted prices, outputs, average variable costs, consumers' surpluses, and producers' rents by seed type, policy, supply situation, and cost per acre for the mobile field sanitizer under each policy for the three postulated supply situations.

**As previously indicated we regard supply situation III as unrealistic. Hence, in the text we suggest potential losses might be realistically estimated to be 20 to 50 percent larger than our "most reasonable" estimates rather than 30 to 100 percent larger as implied by our supply situation III estimates.

Table III.1 Estimated Changes in Consumers' Surplus, Oregon and Non-Oregon Rents, by Seed Type, Supply Situation, Control Policy, and Mobile Sanitizer Cost per Acre (in dollars)

| Seed Type and Supply Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ban on Open Burning | | | Once in Three Years Burning | | | Alternate Year Burning | | |
| | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Ryegrass | | | | | | | | | |
| I. Consumers' Surplus | - 315,227 | - 552,229 | - 777,986 | -213,046 | - 375,484 | - 532,917 | -161,236 | - 284,724 | - 405,389 |
| Oregon Rents | - 704,369 | -1,243,857 | -1,757,380 | -477,578 | - 841,604 | -1,199,814 | -354,266 | - 635,131 | - 909,515 |
| Sum | -1,019,588 | -1,796,086 | -2,535,366 | -690,628 | -1,217,088 | -1,732,731 | -515,502 | - 919,855 | -1,514,904 |
| II. Oregon Rents | - 656,383 | -1,181,363 | -1,706,438 | -437,584 | - 787,565 | -1,137,625 | -328,192 | - 590,682 | - 853,219 |
| III. Oregon Rents | -1,319,285 | -2,264,844 | -3,104,929 | -903,641 | -1,563,869 | -2,188,723 | -682,206 | -1,194,686 | -1,683,997 |
| Tall Fescue | | | | | | | | | |
| I. Consumers' Surplus | -214,336 | -381,887 | -544,252 | -143,029 | -256,700 | -368,095 | -107,040 | -193,041 | -277,744 |
| Oregon Rents | - 63,059 | -110,823 | -156,895 | - 42,647 | - 75,158 | -106,907 | - 32,343 | - 56,969 | - 81,165 |
| Non-Oregon Rents | +148,336 | +273,301 | +402,530 | + 97,525 | +179,172 | +262,726 | + 72,393 | +133,004 | +194,699 |
| Sum | -129,059 | -219,409 | -298,617 | - 88,151 | -152,679 | -212,276 | - 66,990 | -117,006 | -164,210 |
| II. Oregon Rents | - 60,566 | -109,020 | -157,475 | - 40,377 | - 72,680 | -104,984 | - 30,283 | - 54,510 | - 78,737 |
| III. Oregon Rents | - 96,408 | -211,000 | -293,794 | - 82,104 | -133,723 | -203,775 | - 62,005 | -109,742 | -155,791 |
| Red Fescue | | | | | | | | | |
| I. Consumers' Surplus | - 83,745 | -149,086 | -213,146 | - 56,141 | -100,199 | -143,689 | - 42,253 | - 75,483 | -108,394 |
| Oregon Rents | - 90,170 | -160,538 | -228,714 | - 60,566 | -108,110 | -154,772 | - 45,511 | - 81,467 | -116,909 |
| Non-Oregon Rents | + 43,751 | + 79,112 | +114,990 | + 29,112 | + 52,522 | + 76,139 | + 21,848 | + 39,324 | + 56,933 |
| Sum | -130,164 | -230,512 | -326,870 | - 87,595 | -155,787 | -222,322 | - 65,916 | -117,626 | -168,370 |
| II. Oregon Rents | - 60,039 | -108,064 | -156,092 | - 40,012 | - 72,043 | -104,062 | - 30,019 | - 54,032 | - 78,046 |
| III. Oregon Rents | -140,487 | -247,297 | -349,243 | - 94,536 | -167,649 | -238,581 | - 71,244 | -126,788 | -181,098 |
| Chewings Fescue | | | | | | | | | |
| I. Consumers' Surplus | - 54,269 | - 96,869 | -138,712 | - 36,280 | - 64,987 | - 93,346 | - 27,249 | - 48,881 | - 70,324 |
| Oregon Rents | - 67,564 | -120,359 | -172,043 | - 45,249 | - 80,851 | - 88,095 | - 34,020 | - 60,879 | - 77,488 |
| Non-Oregon Rents | + 11,613 | + 21,040 | + 30,644 | + 7,742 | + 13,959 | + 20,248 | + 5,824 | + 10,452 | + 15,127 |
| Sum | -110,220 | -196,188 | -280,111 | - 73,787 | -131,879 | -161,193 | - 55,445 | - 99,308 | -142,685 |
| II. Oregon Rents | - 60,712 | -109,286 | -157,857 | - 40,546 | - 72,857 | -105,238 | - 30,349 | - 54,643 | - 78,928 |
| III. Oregon Rents | -105,171 | -246,053 | -347,686 | - 93,989 | -166,729 | -237,369 | - 70,839 | -126,079 | -180,137 |
| Merion-Kentucky Bluegrass | | | | | | | | | |
| I. Consumers' Surplus | - 22,975 | - 41,286 | - 59,555 | - 15,316 | - 27,316 | -139,788 | - 11,463 | - 20,670 | - 29,854 |
| Oregon Rents | - 24,749 | - 43,787 | - 62,670 | - 12,958 | - 29,193 | - 42,201 | - 12,762 | - 22,318 | - 31,889 |
| Non-Oregon Rents | + 7,936 | + 14,985 | + 22,036 | + 5,005 | + 9,693 | + 14,396 | + 3,541 | + 7,055 | + 10,574 |
| Sum | - 39,788 | - 70,088 | -100,189 | - 23,069 | - 47,051 | - 67,593 | - 20,682 | - 35,933 | - 51,179 |
| II. Oregon Rents | - 22,159 | - 39,884 | - 57,610 | - 14,773 | - 26,589 | - 38,407 | - 11,080 | - 19,942 | - 28,805 |
| III. Oregon Rents | - 40,036 | - 71,173 | -101,938 | - 23,076 | - 47,473 | - 93,782 | - 20,317 | - 36,105 | - 51,725 |
| Bentgrass | | | | | | | | | |
| I. Consumers' Surplus | - 70,163 | -125,173 | -178,984 | - 46,958 | - 84,014 | -120,577 | - 35,279 | - 63,215 | - 90,885 |
| Oregon Rents | -114,057 | -203,063 | -289,895 | - 76,286 | -136,501 | -195,719 | - 57,269 | -102,783 | -147,691 |
| Non-Oregon Rents | + 2,938 | + 5,277 | + 7,709 | + 1,968 | + 3,518 | + 5,093 | + 1,492 | + 2,649 | + 3,821 |
| Sum | -181,240 | -322,899 | -461,170 | -121,276 | -216,997 | -311,203 | - 91,056 | -163,349 | -234,755 |
| II. Oregon Rents | -104,571 | -188,225 | -271,881 | - 69,714 | -125,484 | -181,254 | - 52,286 | - 94,113 | -135,940 |
| III. Oregon Rents | -217,100 | -381,634 | -538,059 | -146,141 | -258,987 | -368,252 | -110,133 | -195,964 | -279,766 |

Source: Appendix G

Table III.2 Estimated Percentage Changes in Consumers' Surplus, Oregon and Non-Oregon Rents, by Seed Type, Supply Situation, Control Policy, and Mobile Sanitizer Cost per Acre (in dollars)

| Seed Type and Supply Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ban on Open Burning | | | Once in Three Years Burning | | | Alternate Year Burning | | |
| | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| **Ryegrass** | | | | | | | | | |
| I. Consumers' Surplus | -10.82 | -18.95 | -26.70 | - 7.31 | -12.89 | -18.29 | - 5.53 | - 9.77 | -13.91 |
| Oregon Rents | -10.63 | -18.76 | -26.51 | - 7.20 | -12.70 | -18.10 | - 5.34 | - 9.58 | -13.72 |
| Sum | -10.68 | -18.82 | -26.57 | - 7.24 | -12.75 | -18.16 | - 5.40 | - 9.64 | -15.87 |
| II. Oregon Rents | - 9.90 | -17.82 | -25.74 | - 6.60 | -11.88 | -17.16 | - 4.95 | - 8.91 | -12.87 |
| III. Oregon Rents | -19.90 | -34.17 | -46.84 | -13.63 | -23.59 | -33.02 | -10.29 | -18.02 | -25.40 |
| **Tall Fescue** | | | | | | | | | |
| I. Consumers' Surplus | - 7.06 | -12.57 | -17.92 | - 4.71 | - 8.45 | -12.12 | - 3.52 | - 6.35 | - 9.14 |
| Oregon Rents | - 8.30 | -14.59 | -20.65 | - 5.62 | - 9.90 | -14.08 | - 4.26 | - 7.50 | -10.69 |
| Non-Oregon Rents | + 9.15 | +16.86 | +24.84 | + 6.02 | +11.15 | +16.21 | + 4.47 | + 8.21 | +12.01 |
| Sum | - 2.39 | - 4.05 | - 5.51 | - 1.63 | - 2.82 | - 3.92 | - 1.24 | - 2.16 | - 3.03 |
| II. Oregon Rents | - 7.97 | -14.35 | -20.73 | - 5.32 | - 9.57 | -13.82 | - 3.99 | - 7.18 | -10.37 |
| III. Oregon Rents | -12.69 | -27.78 | -38.68 | -10.81 | -18.13 | -26.83 | - 8.16 | -14.45 | -20.51 |
| **Red Fescue** | | | | | | | | | |
| I. Consumers' Surplus | - 4.69 | - 8.36 | -11.95 | - 3.15 | - 5.62 | - 8.05 | - 2.37 | - 4.23 | - 6.08 |
| Oregon Rents | - 6.79 | -12.09 | -17.22 | - 4.56 | - 8.14 | -11.65 | - 3.43 | - 6.13 | - 8.80 |
| Non-Oregon Rents | + 3.58 | + 6.47 | + 9.41 | + 2.38 | + 4.30 | + 6.23 | + 1.79 | + 3.22 | + 4.66 |
| Sum | - 3.00 | - 5.32 | - 7.54 | - 2.02 | - 3.59 | - 5.13 | - 1.52 | - 2.71 | - 3.88 |
| II. Oregon Rents | - 4.52 | - 8.14 | -11.75 | - 3.01 | - 5.42 | - 7.83 | - 2.26 | - 4.07 | - 5.88 |
| III. Oregon Rents | -10.58 | -18.62 | -26.29 | - 7.12 | -12.62 | -17.96 | - 5.36 | - 9.54 | -13.63 |
| **Chewings Fescue** | | | | | | | | | |
| I. Consumers' Surplus | - 4.26 | - 7.61 | -10.89 | - 2.85 | - 5.10 | - 7.33 | - 2.14 | - 3.84 | - 5.52 |
| Oregon Rents | - 4.97 | - 8.87 | -12.68 | - 3.33 | - 5.96 | - 6.49 | - 2.51 | - 4.49 | - 5.71 |
| Non-Oregon Rents | + 5.16 | + 9.35 | +13.62 | + 3.44 | + 6.20 | + 9.00 | + 2.59 | + 4.64 | + 6.72 |
| Sum | - 3.86 | - 6.87 | - 9.81 | - 2.58 | - 4.62 | - 5.64 | - 1.94 | - 3.48 | - 5.00 |
| II. Oregon Rents | - 4.47 | - 8.05 | -11.63 | - 2.99 | - 5.37 | - 7.76 | - 2.24 | - 4.03 | - 5.82 |
| III. Oregon Rents | - 7.75 | -18.13 | -25.62 | - 6.93 | -12.29 | -17.49 | - 5.22 | - 9.29 | -13.27 |
| **Merion-Kentucky Bluegrass** | | | | | | | | | |
| I. Consumers' Surplus | - 1.00 | - 1.76 | - 2.54 | - 0.65 | - 1.18 | - 1.70 | - 0.49 | - 0.88 | - 1.27 |
| Oregon Rents | - 2.29 | - 4.05 | - 5.80 | - 1.20 | - 2.70 | - 3.91 | - 1.18 | - 2.07 | - 2.95 |
| Non-Oregon Rents | + 1.00 | + 1.87 | + 2.74 | + 0.62 | + 1.21 | + 1.79 | + 0.44 | + 0.88 | + 1.32 |
| Sum | - 0.94 | - 1.66 | - 2.37 | - 0.55 | - 1.11 | - 1.60 | - 0.49 | - 0.85 | - 1.21 |
| II. Oregon Rents | - 2.05 | - 3.69 | - 5.33 | - 1.37 | - 2.46 | - 3.56 | - 1.03 | - 1.85 | - 2.67 |
| III. Oregon Rents | - 3.71 | - 6.59 | - 9.44 | - 2.14 | - 4.39 | - 8.68 | - 1.88 | - 3.34 | - 4.79 |
| **Bentgrass** | | | | | | | | | |
| I. Consumers' Surplus | - 4.66 | - 8.32 | -11.89 | - 3.12 | - 5.58 | - 8.01 | - 2.34 | - 4.20 | 6.04 |
| Oregon Rents | - 5.82 | -10.35 | -14.78 | - 3.89 | - 6.96 | - 9.98 | - 2.92 | - 5.24 | 7.53 |
| Non-Oregon Rents | + 6.40 | +11.50 | +16.80 | + 4.29 | + 7.67 | +11.10 | + 3.25 | + 5.77 | + 8.33 |
| Sum | - 5.16 | - 9.19 | -13.13 | - 3.45 | - 6.18 | - 8.86 | - 2.59 | - 4.65 | 6.68 |
| II. Oregon Rents | - 5.33 | - 9.60 | -13.86 | - 3.55 | - 6.40 | - 9.24 | - 2.67 | - 4.80 | 6.93 |
| III. Oregon Rents | -11.07 | -19.46 | -27.44 | - 7.45 | -13.21 | -18.78 | - 5.62 | - 9.99 | 14.27 |

Source: Appendix G

## D. Changes in Agricultural Land Values under Alternative Open Field Burning Control Policies

We conclude this portion of the report by presenting our estimates of the decrease in the value of Willamette Valley agricultural land under alternative open field burning control policies. These estimates are based on data and statistical results reported in the previous section and appendices E and G. Two assumptions underlie these estimates: (1) the control policies under investigation here have no impact on the marginal physical products of land, specialized equipment, special entreprenuerial abilities, etc.; and (2) the policies do not significantly alter the contribution of urban influences to Willamette Valley agricultural land values. The first assumption seems reasonable because use of the mobile field sanitizer would require no fundamental changes in cultivation or production practices and, in addition, is postulated here to have no impact on yields per acre. Hence, the sanitizer would raise costs per unit of output but not affect marginal products. The second assumption is based on our judgment that demands for land in alternative uses to seed production would not shift because the attractiveness of the Valley increases as open field burning is controlled. Consequently, the already existing and projected urban influences on agricultural land values may reasonably be assumed unchanged by adoption of the control policies under study here.

Under the assumptions specified above, the percentage decrease in the difference between price and average variable cost would equal the percentage decrease expected in rents received by land and other commonly regarded "fixed" factors in grass seed production. In Table III.3, column (1) presents this percentage decrease for supply situation II, where all "fixed" factors remain in seed production after open field burning controls are introduced, and column (2) presents the percentage decrease for supply situation I, where some "fixed" factors leave seed production to receive payments at least equal to those they could receive in seed production. Of course, if current and expected future earnings in agricultural use were highly correlated, and if current land values approximately equalled the capitalized value of current earnings in perpetuity, then these percentage decreases would respectively measure the maximum and minimum percentage decreases expected in agricultural land values consequent to each open field burning control policy. Appendix E, however, provides conclusive evidence that neither of these conditions are satisfied in the Willamette Valley, where distance-to-town is an exceedingly important independent variable in statistically explaining variations in agricultural land values.

Given that agricultural land values per acre substantially exceed the capitalized value of estimated rents per acre at interest rates of 8, 9, 10 or more percent, land values would be anticipated to decline less than the percentages reported in columns (1) and (2) in Table III.3. To predict by how much land values would decline in the Willamette Valley generally following implementation of each open field burning control policy, we employ the all-counties regression results reported in Table III.4 of appendix E. Since that regression equation was estimated in log-log form, we obtain columns (3) and (4) of Table III.3 by multiplying the percentages given in the first two columns by 0.6333, the regression coefficient for estimated rent per acre (which also served as a soil quality index in appendix E). The final column of Table III.3 simply averages our maximum and minimum predicted declines in land values to provide our "most reasonable" estimate of the declines that would be associated with different control policies under different assumption concerning the cost per acre of the mobile field sanitizer.

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Table III.3. Predicted Percentage Decreases in Willamette Valley Agricultural Land Values Under Alternative Open Field Burning Control Policies, By Policy and Under Various Assumptions

| Policy | Mobile Sanitizer Cost per Acre | Decrease in Price minus Average Variable Cost | | Predicted Decrease in Agricultural Land Values | | |
|---|---|---|---|---|---|---|
| | | Supply Situation II (1) | Supply Situation I (2) | High Estimate[a] (3) | Low Estimate[b] (4) | Average Estimate[c] (5) |
| Ban on Burning | $ 5 | 7.35% | 4.48% | 4.65% | 2.83% | 3.74% |
| | 9 | 13.24 | 6.61 | 8.38 | 4.19 | 6.29 |
| | 13 | 19.12 | 9.91 | 12.11 | 6.28 | 9.20 |
| Once in Three Years Burning | 5 | 4.90 | 2.61 | 3.10 | 1.65 | 2.48 |
| | 9 | 8.82 | 4.62 | 5.86 | 2.93 | 4.35 |
| | 13 | 12.75 | 6.69 | 8.07 | 4.23 | 6.15 |
| Alternate Year Burning | 5 | 3.68 | 1.92 | 2.33 | 1.22 | 1.88 |
| | 9 | 6.62 | 3.47 | 4.19 | 2.20 | 3.20 |
| | 13 | 9.56 | 5.01 | 6.05 | 3.17 | 4.61 |

Source: Tables G.1-G.6

[a] Col. (1) x 0.633

[b] Col. (2) x 0.633

[c] [Col. (3) + Col. (4)]/2

At first blush, this procedure probably appears to "over-interpret" our regression results. After all, those regression results purport only to explain variations about mean land values among our sample observations. Although the rent coefficient could be used to predict the difference in value between two properties given the rents on all other land within the Valley, most economists would argue that such regression coefficients cannot be used to predict changes in the general pattern of values or changes in the aggregate value of all properties when the pattern or level of rents across the entire Valley changes.* In most instances we would agree with this objection to our procedure, but in this case we would not agree for the following reasons. The regression results in Tables E. 2 and E.4 show rent-per-acre regression coefficients having magnitudes which imply that declines in rents would be perfectly capitalized into lower land values at interest rates of 9-11 percent. Since (1) marginal rates of return in the private sector vary from 8 to 12 percent and (2) agricultural land values in the Valley greatly exceed capitalized estimated rents at the foregoing interest rates, we regard the estimates in columns (3)-(5) of Table III.3, which do imply perfect capitalization of rent decreases at reasonable interest rates, as probable overestimates of the decline in land values realistically expected to follow introduction of each control policy.

In conclusion, we report the estimates in Table III.3 simply to provide additional perspective on the implications of the three open field burning control policies under investigation in this report.

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[*] We readily admit that this would surely be the case following implementation of open field burning control policies on the scale investigated here.

# IV. THE BENEFITS OF ALTERNATIVE OPEN FIELD BURNING CONTROL POLICIES

## A. Introduction

As indicated in the introduction to this report, open burning of agricultural fields takes place between mid-July and late September, and the resulting smoke constitutes a major seasonal air pollution problem for Oregon authorities. Most concern has arisen about the visibility reductions associated with this agricultural practice. Since the burning occurs at the height of the tourist and resident vacation and outdoor-recreation seasons and the desirability of such activities intuitively appears to vary directly with visibility, many Willamette Valley residents argue that tourists and residents select different activities, alter their expenditure patterns, and experience a rather pervasive decline in the quality of their environment because of field burning.

In contrast to pollution problems elsewhere, there is little or no concern about the effect of field burning smoke on health, soiling, materials damage, land values, or the selection of plant locations and/or production processes by existing or potential industries in the Willamette Valley. Undoubtedly the relatively short burning season and the quite variable pollution levels experienced at different locations combine to explain this absence of concern. In fact, there is exceptionally little "hard" evidence on these matters, largely because most strategies for measuring the effects of pollution require persistent and stable differences in air quality. Consequently, since smoke from open field burning is neither persistent nor consistently distributed throughout the Valley for very long periods, measurement of the benefits associated with alternative field burning control policies required us to focus on air quality as (1) a determinant of the "state of the environment" experienced by residents and tourist and (2) a determinant of household recreation and vacation activities.

In section B below, we develop measures of the improvement in visibility that would occur under alternative policies restricting acres burned. There, we measure changes in the visibility component of the public good which we term "the state of the environment." Our measurement index is aggregate-people-miles-of-minimum-visibility, and we follow standard benefit measurement practice by measuring the policy-induced changes in that index from a base representing optimal field burning practice. No attempt to value these changes in a "public good" is made in this section. Instead, valuation questions are addressed in Part V of the report.

In section C, attention turns to Willamette Valley resident outdoor recreational activity under alternative field burning control policies. Estimates of the value of increases in resident recreation activity are

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developed by employing the results of empirical investigations reported in appendixes D and H, estimates of visibility changes from section B, and unit-recreation-activity values suggested by the Water Resources Council.

Three additional observation are appropriate here. First, no estimates of the impact of changes in air quality on tourist-behavior in Oregon are reported here. In fact, the multi-variate statistical analysis of tourist survey data presented in appendix H discovered no support for the hypothesis that tourist behavior in Oregon in August 1971 was affected by air quality deterioration due to smoke from open field burning. Consequently, at least for now, we must conclude that tourist behavior, once committed to an Oregon vacation, is largely unaffected by pollution conditions which they discover in the Willamette Valley. Tourists typically pass through the Valley on route to the coastal, plain, or mountain attractions which brought them to Oregon. They are therefore exposed to the effects of open field burning for relatively short periods when compared to residents, and hence it is not too surprising that tourist behavior is not statistically significantly affected by air quality variation in the Valley.

This brings us to our second observation. The absence of evidence that visibility restrictions due to open field burning smoke do affect short-run tourist decisions once they have embarked on an Oregon vacation does not establish whether or not significant longer-run effects exist. For example, the rate at which tourists return to Oregon during their future vacations conceivably may be affected marginally by their exposure to the effects of open field burning. Unfortunately no evidence is now available either to support or to refute this hypothesis. To generate "hard" empirical evidence on this and most other conceivable effects of open field burning would appear to us to require a misallocation of research effort. In our view, the major benefits of alternative field burning control policies are received by Willamette Valley residents in the form of an improved "state of the environment," and the magnitudes of these benefits are reasonably well-estimated in sections B and C below.

Finally, the measurement index developed here is not intended to imply that individuals' attitudes toward, and presumably valuations of, improvements in visibility do not exhibit considerable variation. Available evidence for Eugene and Salem reveals that such an assumption would grossly misrepresent the facts.*

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*See Robert G. Mason, *The Effect of Air Pollution on Public Attitudes and Knowledge*, a report prepared for APCO,EPA under the same contract with Oregon State University as this report (Corvallis, Oregon: June 1972).

## B. Visibility Under Alternative Field Burning Control Policies

In appendix D of this report and in our second annual report, we have presented strong evidence that (1) variations in acres-burned statistically explain a major fraction of observed variations in minimum daylight visibility in Eugene and Salem and (2) DEQ policies regulating acres-burned according to present and predicted meteorological conditions have reduced smokiness and increased minimum visibility in Eugene while producing the opposite effects for Salem. We have also employed 1971 burning season data and our multiple-regression findings to calculate equations which relate minimum visibility in Eugene and Salem to relevant acres-burned (see the final section of appendix D). Since increases in south Willamette Valley acres-burned under northerly wind conditions reduce visibility in Eugene, while increases in south acres burned under southerly wind conditions reduce minimum visibility in Salem, we now employ our calculated pollution production function equations to determine how alternative burning programs with respect to south Valley acres in 1971 would have affected visibility in Eugene and Salem. Put slightly differently, we seek to determine the optimal burning program for south Willamette Valley acreages. Only after the specification of the optimal burning program with no in total acres burned can one measure the genuine gains in visibility attributable to reductions in acres burned.

In 1971, 132,000 acres were burned in the southern half of the Willamette Valley on the 25 days with meteorological conditions compatible with those postulated in our estimation of pollution production functions for Eugene and Salem. Since only 170,000 acres were burned in the south Valley during the entire 1971 burning season, we do not believe that it is unreasonable to characterize an optimal program based on just 25 days for our present purposes, though we would urge cautious, additional research before actual implementation of the optimal program presented here. Finally, in making the required computations, we postulate that northerly winds occur on 16 days and southerly winds on 9 days -- those conditions exactly matching what in fact occurred in 1971.

Granted the value judgment that miles of minimum visibility in Salem and Eugene are equally valuable per affected individual,* the optimal acreage to burn under southerly wind conditions, $X^o$, may be obtained by maximizing the following welfare function:

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*Although other value judgments are possible, none appear more reasonable than this one. Moreover, none of our conclusions would change if we postulate that miles of minimum visibility in either Salem or Eugene were 2,3,4, or even 5 times more valuable at the margin than in the other city. Evidence to support this judgment is provided below.

$$W = w16N_EV_E + 9N_SV_S \qquad (16)$$

where $w$ = welfare weight for miles of minimum visibility per affected person in Eugene,

$N_E$ = number of persons in Eugene urban area,

$N_S$ = number of persons in Salem urban area,

$V_E = 11.3 - 0.00418\left(\frac{132{,}000-X}{16}\right) + 7.127 \times 10^{-6}\left(\frac{132{,}000 - X}{16}\right)^2$ ,

$V_S = 14.0 - 0.0006\left(\frac{X}{9}\right) + 1.792 \times 10^{-8}\left(\frac{X}{9}\right)^2$ ,

or $V_S = 14.0 - 0.00036\left(\frac{X}{9}\right)$

$X$ = south Willamette acres-burned under southerly wind conditions.*

One obtains the value of X which would maximize this function by setting its partial derivative with respect to X equal to zero and solving for $X^o$. Interestingly, the same solution is obtained with non-linear or linear pollution production functions: $X^o > 132{,}000$ with $w = 1$. Therefore, the optimal burning program with respect to south Willamette Valley acres requires that all acres be burned under southerly wind conditions, none under northerly wind conditions. Moreover, this result is not sensitive to changes in total acres burned (at least up to 170,000) or moderate changes in postulated minimum visibilities in the absence of field burning.

The three major reasons for this result are easily stated. First, a given increase in daily acres-burned under northerly wind conditions reduces minimum visibility in Eugene approximately 7 to 11 times more than the same increase under southerly wind conditions would reduce visibility in Salem. Visibility in Eugene is clearly more sensitive to smoke from open field burning than Salem. Second, other things equal, Salem minimum visibilities exceed those in Eugene by a substantial margin. Thus, changes in Salem visibility are necessarily absolutely and relatively smaller in response to field burning than those in Eugene. Third, the Eugene urban area is more populous than the Salem area (139,319 v. 92,866 according to the 1970 U.S. Census), thereby weighting miles of minimum visibility in Eugene more heavily.

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*The pollution production function equations are taken from appendix D. These functions are based on 1971 data which, of course, is quite appropriate in the present context.

Two further interesting conclusions can be reached with the aid of our proposed welfare function. With w = 1, one can compute W under (a) the actual 1971 burning program where X = 117,000 acres and (b) the optimal burning program where X = 132,000. Under the actual 1971 program W equals 25,628,000 people-miles-of-visibility (pmv), while under the optimal program W equals 32,757,000 pmv with non-linear Salem pollution production function, or 32,477,000 pmv with the linear Salem function. Although such numbers must be interpreted with care, they do afford an opportunity to develop indexes to measure improvements in air quality. This is done below. Second, one can calculate the value of w implicit in the 1971 burning program by setting X equal to 117,000 and finding the value of w which would result in the partial derivative of (16) with respect to X equal to zero. When this was done, we found w equalled 0.0555. In words, the marginal value of improvements in Eugene minimum visibility implicit in the 1971 burning program appear to have been only about 6 percent of the marginal value of improvements in Salem. Of course, this finding must be interpreted with great caution. We do not wish to imply that the DEQ burning program has been consciously designed to generate larger benefits for Salem than Eugene; we know that this is definitely not the case because with no regulation of field burning Salem visibility would be greater and Eugene visibility lower; and we know that the DEQ burning program has purposefully been designed to improve Eugene visibility to the disadvantage of Salem. Instead we wish to stress that, if miles of visibility in the Salem and Eugene urban areas are treated as equally valuable per person and our pollution production functions are accurate, future DEQ burning programs should increase south Valley acres burned under southerly wind conditions. Despite the predictable deterioration in Salem visibility associated with this type of program, it would be consistent with maximization of at least one one "reasonable" welfare function.*

Although all other burning programs associated with no reduction in total acres burned in the south Valley result in fewer people-miles-of minimum-visibility than the optimal policy of burning only under southerly wind conditions, we would be remiss not to report our findings concerning at least three of these policies. The three policies examined have the following objectives: (1) absolute equality of minimum daylight visibility in Eugene and Salem; (2) equality of the absolute declines in minimum daylight visibility in the two cities; and (3) equality in the relative declines in minimum daylight visibility in each city. To determine the appropriate acreage to be burned under southerly wind conditions, we employ our calculated pollution production function equations presented above and solve the following three equations for X:

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*The adoption of the optimal burning program would not appreciably increase the implicit marginal value of improvements in Eugene minimum visibility. Under the optimal policy, w = 0.0574 or just 3.6 percent more than under the 1971 burning program. Therefore, as noted in an earlier footnote, none of our conclusions would be changed if we postulated miles of minimum visibility in Salem to be considerably more valuable at the margin than in Eugene. In a very important sense, in this instance alternative specifications of the parameters and forms of the social welfare function would have no impact (except in extreme cases) on our conclusions.

$$V_E = V_S \qquad \text{(Absolute Equality)}$$

$$11.3 - V_E = 14.0 - V_S \qquad \text{(Equal Absolute Declines)}$$

$$\frac{(11.3 - V_E)}{11.3} = \frac{(14.0 - V_S)}{14.0} \qquad \text{(Equal Relative Declines)}$$

Our solutions to these equations indicated that approximately 122,000 South Valley acres should be burned under southerly wind conditions to assure that Salem has the same visibility as Eugene when 10,000 acres are burned under northerly wind conditions. In contrast, to achieve equal absolute and relative declines in Salem and Eugene minimum visibilities, about 112,000 and 110,000 acres, respectively, should be burned under southerly wind conditions, the remaining 20,000 and 22,000 acres being burned under northerly wind conditions.

Undoubtedly the most remarkable feature of these results is that they neatly bracket the south Willamette Valley acreage actually burned under the 1971 DEQ burning program. Although these policies fail to consider the numbers of persons experiencing visibility restrictions due to open field burning, none of the policies can be regarded as particularly outlandish. Therefore, our findings here provide additional evidence that the present DEQ burning program is basically sound; our single recommendation for improvement would be to increase acres burned under southerly wind conditions.

We now turn to perhaps our most interesting and important task, the estimation of the net change in total people-miles-of-minimum-visibility (pmv) under three alternative policies regulating open field burning. Our procedure is rather straight-forward and begins with the estimation of total people-miles-of-minimum-visibility in the Willamette Valley on the 27 days during 1971 for which our statistical investigations (see appendix D) suggest minimum daylight visibilities in Salem and Eugene are predictably related to acres burned in different zones of the Valley. Table IV. 1 reports these estimates for the optimal burning program with no reduction in acres burned and three alternative policies regulating burning, as well as the particular estimates of population and expected miles of minimum visibility which underlie the total pmv estimates.*

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*Although our best estimates of minimum daylight visibility in Salem under southerly wind conditions are based on the non-linear pollution production function equation presented earlier in this section, in the notes to Table IV. 1 we also report estimates based on the linear equation $V_S = 14.0 - 0.00036\ (X/9)$. We do this because such differences in functional form have considerable effect on our total pmv estimates for Salem under the optimal burning program and thereby influence our estimates of the net change in total pmv for the Valley under different policies.

Table IV.1. Estimates of Total People-Miles-of-Minimum-Daylight-Visibility Under Alternative Open Field Burning Policies for 27 Days in the 1971 Burning Season

| | Optimal Open Burning | Ban on Open Burning | Alternate Year Open Burning | One in Three Years Open Burning |
|---|---|---|---|---|
| North Winds, 18 Days | | | | |
| North Valley population | 340,000 | 340,000 | 340,000 | 340,000 |
| North acres burned | 24,066 | — | 12,033 | 8,022 |
| Salem minimum visibility | 10.67 | 13.80 | 12.17 | 12.70 |
| Total North Valley pmv | 65,300,000 | 84,456,000 | 74,480,000 | 77,724,000 |
| South Valley population | 340,000 | 340,000 | 340,000 | 340,000 |
| South acres burned | 15,000 | — | — | — |
| Eugene minimum visibility | 11.30 | 11.30 | 11.30 | 11.30 |
| Total South Valley pmv | 69,156,000 | 69,156,000 | 69,156,000 | 69,156,000 |
| South Winds, 9 Days | | | | |
| North-Valley-plus population | 450,000 | 450,000 | 450,000 | 450,000 |
| South acres burned | 132,000 | — | 66,000 | 44,000 |
| Salem minimum visibility | 9.06[a] | 14.0 | 10.56[b] | 11.92[c] |
| Total North-Valley-plus pmv | 36,673,000[d] | 56,700,000 | 42,768,000[e] | 48,276,000[f] |
| North-Valley-minus population | 110,000 | 110,000 | 110,000 | 110,000 |
| North acres burned | 10,346 | — | 5,173 | 3,449 |
| Salem minimum visibility | 10.67 | 14.00 | 12,34 | 12.89 |
| Total North-Valley-minus pmv | 10,563,000 | 13,860,000 | 12,216,700 | 12,761,000 |
| Eugene area population | 200,000 | 200,000 | 200,000 | 200,000 |
| Eugene minimum visibility | 15.1 | 15.1 | 15.1 | 15.1 |
| Eugene area pmv | 27,180,000 | 27,180,000 | 27,180,000 | 27,180,000 |
| Willamette Valley Totals, 27 Days | | | | |
| Total acres burned | 181,412 | — | 83,206 | 55,471 |
| Total Valley pmv | 208,872,000[g] | 251,352,000 | 225,801,000[h] | 235,097,000[i] |

Note: See the text for sources and computations procedures.

a Linear function estimate = 8.72
b Linear function estimate = 11.36
c Linear function estimate = 12.24
d Linear function estimate = 35,316,000
e Linear function estimate = 46,008,000
f Linear function estimate = 49,572,000
g Linear function estimate = 207,516,000
h Linear function estimate = 229,041,000
i Linear function estimate = 236,393,000

Three comments concerning these estimates are in order. First, although our estimates of the populations in various zones of the Willamette Valley affected by open field burning smoke under specified wind conditions are not presented with great confidence, we do believe that they are of the "right order of magnitude." Second, we employ minimum visibility estimates for Eugene and Salem as estimates of visibility for large zones of the Valley with much reluctance. However, there is no alternative because visibilities are not regularly reported at other locations in the Valley. Third, we employ our calculated pollution production function for Salem under northerly wind conditions to estimate minimum visibility in the northern portion of the Valley under southerly wind conditions when north Valley acres are burned; again, in the absence of other evidence, we adopted this procedure to develop total pmv estimates that "appear to be of the right order of magnitude."

For these reasons we must admit that there are sources of unreliability both in the data and in the concepts employed to obtain the total pmv estimates for each zone of the Valley under different wind conditions. Moreover, since we have no independent estimates of the zone totals, the total pmv estimates for the full 27 days have all the unreliabilities that their components in combination contribute. Nonetheless, we doubt that the total pmv estimates are more than 15 percent either way from the "true" figures.

Of course, the expected net increase in total pmv attributable to each alternative open field burning policy for the 27-day portion of the 1971 burning season is obtained by substracting the total pmv attainable under the optimal burning program (i.e., burn all south Valley acres under southerly wind conditions) from the total pmv associated with each policy. The first column of Table IV.2 reports these figures. It should be recalled that this procedure purposely excludes increases in pmv attainable with no reduction in total acres burned from the increases in pmv attributable to policies that reduce total acres burned. To do otherwise would overstate the genuine net increase in total pmv attributable to each policy.

Since we have been unable to estimate satisfactory models to predict how minimum daylight visibility would vary with changes in acres burned under all, meteorological conditions, we must employ an extrapolative procedure to obtain estimates of the increase in total pmv for the entire 1971 burning season. Following careful examination of the alternatives, we decided that it would be best to use an extrapolative technique based on (a) the estimated increase in total pmv attainable in the 27-day period and (b) the percentage of total Valley acreage burned during the remainder of the burning season. In 1971, 181,412 acres of the total 233,379 acres were burned during the 27-day for which we have estimated total pmv in the Valley; the remaining 41,967 acres, or 22.27 percent of the total, were burned during the other 50 days in the season.*

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*State of Oregon, Department of Environmental Quality, Air Quality Control Division, *Field Burning in the Willamette Valley, 1971*, a report date April 30, 1972, Table II, pp. A4-7.

Table IV.2. Estimates of the Expected Increase in People-Miles-of-Minimum-Daylight-Visibility Under Alternative Open Field Burning Policies for the 1971 Burning Season.

| Assumed Pollution Production Functions and Open Field Burning Policies | Willamette Valley Residents | | Tourists[c] |
|---|---|---|---|
| | 27 Days[a] (1) | Season[b] (2) | Season (3) |
| Non-linear Functions | | | |
| Ban on open burning | 42,480,000 | 53,100,000 | 5,310,000 |
| Alternate year open burning | 16,929,000 | 21,161,000 | 2,116,000 |
| Once in three years open burning | 26,225,000 | 32,781,000 | 3,278,000 |
| Linear Function for Salem | | | |
| Ban on open burning | 43,836,000 | 54,795,000 | 5,480,000 |
| Alternate year open burning | 21,525,000 | 26,906,000 | 2,691,000 |
| Once in three years burning | 28,877,000 | 36,096,000 | 3,610,000 |

a Derived from Table IV.1 as explained in text.
b Col. (1) x 1.25
c Col. (2) x 0.10

Given that the remaining 52,000 acres would be burned over a period almost twice as long as that period in which 181,000 acres were burned, it appeared reasonable to increase our 27-day estimates by 25 percent to obtain estimates of the net increase in total pmv for the full burning season in 1971. The second column of Table IV.2 indicates our basic estimates of the total increase in people-miles-of-minimum-visibility that Willamette Valley residents would have experienced during the 1971 burning season under each of the three policies restricting open field burning.

Next we turn to estimation of the total days spent in the Willamette Valley during the 1971 field burning season by out-of-state tourists. Perhaps 75 percent of the almost 6 million out-of-state summer tourists visited Oregon during the field burning season. Well-informed Oregon State Highway Division personnel suggest that possibly 80 percent of these visitors spend one day in the Willamette Valley during their average 3.9 days in Oregon. Consequently, we estimate that out-of-state tourists spent approximately 3.6 million days in the Willamette Valley during the 1971 burning season.*

Since the 680,000 Willamette Valley residents spent about 40 million days in the Valley during the 1971 field burning season, out-of-state tourists would constitute slightly less than 10 percent of the population potentially affected by field burning. If one assumes that residents and tourists are similarly exposed to visibility reductions from open field burning, out-of-state tourists would experience increases in total pmv equal to perhaps 10 percent of the increase experienced by Valley residents. On these assumptions, the third column of Table IV.2 presents our "most reasonable" estimate of the total increase in people-miles-of-minimum-visibility that out-of-state tourists in the Willamette Valley would have experienced under each of the three policies restricting open field burning.

Finally, Table IV.3 puts our estimates of the increases in visibility under each of the three policies in slightly different perspective by expressing the increases as a percentage of the totals attainable under the optimal burning program. Of course, how substantial one judges these increases to be depends on how much one values improved minimum daylight visibility. In the concluding part of this report, the estimates presented in Table IV.2 are used to determine the minimum marginal value of visibility improvements required for each of the three policies restricting open field burning to have benefit-cost ratios equal to one.

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*The estimates made in this paragraph were developed from data reported in *1971 Out-of-State Tourist Revenue Study*, a report by the Economics Unit, Planning Section, Oregon State Highway Division, dated February 1972, following consultation with Highway Division economists.

Table IV.3. Percentage Increases in People-Miles-of-Minimum-Daylight-Visibility Under Alternative Open Field Burring Policies for the 1971 Burning Season

| Policy | Salem Pollution Production Function Under Southerly Winds | |
|---|---|---|
| | Non-linear | Linear |
| Ban on open burning | 20.34% | 21.03% |
| Alternate year open burning | 8.10 | 10.37 |
| Once in three years open burning | 12.56 | 13.92 |

Note: Percentages calculated with Willamette Valley totals, Table IV.1, and increases in totals, column (1) of Table IV.2.

## C. Resident Outdoor Recreational Activity Under Alternative Field Burning Control Policies

In appendix H of this report, Sorenson has presented the results of his empirical investigations of attendance or use at certain public or private facilities in Eugene and Salem. That investigation employed multiple regression analysis to examine the determinants of swimming pool and golf course use, as well as the number of visitors at the Oregon State Capitol Building in Salem and overnight campers at Armitage State Park near Eugene. Attendance or use was treated as the dependent variable, while the independent variables include minimum daylight visibility, high temperature, and day of the week. The emprical results obtained must be regarded as mixed, particularly with respect to the statistically suggested zero relationships between rounds of golf, indoor swimming pool attendance in Eugene, and minimum visibility. On the other hand, the estimated relationships between minimum visibility and attendance at outdoor swimming pools in both Eugene and Salem were positive and statistically significantly different from zero at the 95 or 99 percent confidence level. Overall, Sorenson concluded that his statistical results provided substantial presumptive and empirical support for the hypothesis that air quality affects the extent to which individuals undertake outdoor recreational activities. He further suggests that the evidence supports the hypothesis that consumers in fact do engage in activity substitution under variation of air quality.

Here, however, we accept Sorenson's findings and inquire into the magnitudes and values of recreational activity changes induced by variations in air quality. We begin this exercise by presenting the arc-elasticities of swimming pool attendance in Salem and Eugene with respect to minimum daylight visibility:

| | |
|---|---|
| Eugene, outdoor public pools | 0.18 |
| Eugene, indoor public pools | 0.10 |
| Eugene, all public pools | 0.16 |
| Salem, outdoor public pools | 0.20 |

These elasticities were calculated from Sorenson's study over the range of minimum visibilities in Eugene and Salem associated with the optimal burning program and the three policies restricting open field burning under investigation. Only the indoor public pool elasticity in Eugene is calculated with a statistically insignificant regression coefficient.

The above elasticities assume major importance here because (1) a large fraction of the Eugene and Salem area populations has relatively easy access to the pools under study, (2) swimming is clearly the number one outdoor recreational activity for Willamette Valley residents during the field burning season, and (3) a high proportion (perhaps 50-75 percent) of all swimming activity undertaken by residents occurs at locations where visibility is commonly affected by smoke from open field burning.* Given our estimate that Willamette Valley residents swam on 1.5 to 2.3 million occasions in zones affected by field burning smoke during the typical recent season, the above elasticities imply that the 20 percent improvement in visibility associated with a ban on open field burning (see Table IV.3) would increase the days on which residents swim by 60,000 to 90,000. Although the implied 4 percent increase in swimming activity appears small, it amounts to the not inconsiderable sum of $30,000 to $45,000 when valued at the admission fee of $0.50 charged adults at Salem and Eugene public pools.

Moreover, at a minimum, these calculations based on relatively "hard" numbers suggest that the value of outdoor recreational activity affected by visibility restrictions due to open field burning may be quite substantial. For example, if other outdoor recreational activity were both affected by field burning smoke and valued similarly to swimming, which constitutes about 16 percent of total resident recreational activity, then a ban on open field burning might result in an increase in recreational activity valued between $180,000 and $270,000. However, the theory and regression results presented in appendix H suggests that these figures probably inaccurately value outdoor recreational experiences foregone by Valley residents because of visibility restrictions due to open field burning for the following reasons. First, there is no evidence to support the hypothesis that all outdoor recreational activities engaged in by Willamette Valley residents are affected similarly by variations in visibility.** In fact, appendix H reports evidence refuting this hypothesis and suggesting that some outdoor activities may hardly be affected at all. Second, individuals very probably substitute one recreational activity for another within the field burning season or in some other season, thereby reducing the net impact of variations in visibility due to open field burning. Third, not all resident outdoor recreational activity is undertaken within the Willamette Valley. On the contrary, Valley residents are peripatetic outdoor recreators who regularly travel to coastal and mountainous areas to engage in what we classify as recreation activities here.

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*An as-yet unpublished, Oregon State Highway Division telephone survey of recreational activities engaged in by Oregon residents, by county, provides data suggesting that swimming activity constitutes 16.7 percent of total Willamette Valley resident recreational activity during the field burning season. Pleasure driving, bicycling, picnicking, and outdoor games are ranked 2 through 5 by Valley residents for the burning season. All numbers of persons participating in outdoor recreational activities cited in the text are derived from this Highway Division survey.

**The types of outdoor recreation activity to which we have reference here include: fishing, boating and water skiing, swimming, camping, hunting, bicycling, horseback riding, playing outdoor games and sports, picnicking, walking for pleasure, hiking, nature study, rockhounding, etc., pleasure driving, sightseeing, attending outdoor sporting or cultural events, playing golf, and others feasible during the summer months in the Willamette Valley. Each of these activities was surveyed in the Highway Division study referred to earlier.

For the above reasons, we consider it unreasonable to assume that the elasticity of aggregate resident recreational activity with respect to minimum daylight visibility is as high as 0.2, and we therefore assume that it equals 0.1 to calculate the increases in aggregate resident recreational activity presented in Table IV.4. There, our high, medium, and low estimated increases assume that 90,70, and 50 percent of residential recreational activities are undertaken within the Willamette Valley and potentially affected by restrictions in visibility due to open field burning smoke. Our medium estimate of 70 percent is probably the most realistic figure for each policy.

The final three columns of Table IV.4 present our estimates of the value of outdoor recreational activities foregone by Willamette Valley residents because of visibility restrictions due to open field burning. The estimates are based on the range of values suggested for the evaluation of outdoor recreation days by the Water Resources Council.* Since these values were developed as single unit values to be "assigned per recreation day regardless of whether the individual engages in one activity or several," we regard the estimates at each value in Table IV.4 to be relatively generous because the basic data we used treated each activity separately although it is certain that residents engaged in more than one activity per day on numberous occasions. In any event, given individual abilities to substitute other valuable activities for outdoor recreational activities, our best estimates of the value of increases in Willamette Valley resident outdoor recreation activity consequent to the three policies under investigation would be as follows: (1) $249,000 for a ban on open burning, (2) $111,000 for a policy allowing alternate year open burning, and (3) $160,000 for a policy allowing open burning once in three years.

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*See Water Resources Council, *Evaluation Standards for Primary Outdoor Recreation Benefits,"* Supplement No. 1 to U.S. Senate Document No. 97 (87th Congress, 1964), pp.4.

Table IV.4. Number and Value of Increases in Willamette Valley Aggregate Outdoor Residential Recreational Experiences Under Alternative Open Field Burning Policies for the 1971 Burning Season.

| Field Burning Policy | Percent of Activities Undertaken Within Valley | Increase in Resident Recreational Experiences[a] | Value of Increased Resident Recreational Experiences | | |
|---|---|---|---|---|---|
| | | | $0.50 | $1.00 | $1.50 |
| Ban in Open Burning | 90 | 320,000 | $160,000 | $320,000 | $480,000 |
| | 70 | 249,000 | 124,500 | 249,000 | 373,500 |
| | 50 | 178,000 | 89,000 | 178,000 | 267,000 |
| Alternate Year Burning | 90 | 142,000 | 71,000 | 142,000 | 213,000 |
| | 70 | 111,000 | 55,500 | 111,000 | 166,500 |
| | 50 | 79,000 | 39,500 | 79,000 | 118,500 |
| Once in Three Years Burning | 90 | 205,000 | 102,500 | 205,000 | 307,500 |
| | 70 | 160,000 | 80,000 | 160,000 | 240,000 |
| | 50 | 114,000 | 57,000 | 114,000 | 171,000 |

[a] Increase = (0.1)(v)(f)(17,130,000), where 0.1 = assumed elasticity of aggregate resident recreational activity with respect to minimum visibility, v = average percent change in visibility under each policy (from Table IV.3), f = percent of activities undertaken within the Willamette Valley, and 17,130,000 is our estimate of aggregate 1971 resident outdoor recreation experiences (derived from Oregon State Highway Division special survey of recreational activity in Oregon).

# V. A CONTRIBUTION TO THE EVALUATION OF ALTERNATIVE OPEN FIELD BURNING CONTROL POLICIES

To conclude this investigation of the benefits and costs of alternative open field burning control policies, we draw together our best estimates of the benefits and costs of each policy. We do not report benefit-cost ratios, net present values or rates of return for each policy, however. We do not calculate such evaluative indexes because we have not been able to devise any practical technique for measuring the marginal value of increases in the public good "improved visibility." On the other hand, we do attempt to contribute to the evaluation of the policies by providing estimates of their respective implicit total, average, and marginal costs. Unquestionably our most interesting finding is that improvements in Willamette Valley visibility are produced under conditions of decreasing average costs.

Table V.1 presents the "most reasonable" benefit and cost estimates developed in the two preceding parts of this report. Column (2) indicates the decrease in aggregate Oregon producer rents in supply situation I, by field burning control policy and by alternate assumed costs per acre for the mobile field sanitizer. In contrast, column (3) reports the sum of our predicted changes in Oregon and non-Oregon producer rents and consumers' surpluses (or what is often termed "total social loss"), again assuming supply situation I. As we indicated in part III and appendix F, although we would not claim our postulated supply and demand functions perfectly reflect industry conditions as they were during the late sixties, we do believe the aggregate estimates in columns (2) and (3) are tolerably accurate.

In contrast, we have much less confidence in our valuations and predictions of the increase in Willamette Valley resident outdoor recreation activity. For this reason, column (4) presents our highest, lowest, and median estimate under each policy. We prefer to make our uncertainty in this respect obvious because these benefits affect the net measurable cost estimates reported in columns (5) and (6) so very much. We provide estimates of net measurable costs from both an Oregon and national viewpoint because either could conceivably be considered relevant under various circumstances.

Several observations concerning the estimates in Table V.1 are appropriate here. First, the decrease in Oregon producers' aggregate rents under each policy is quite substantial in both absolute and relative terms. Our estimates range from a minimum of $0.536 million to $2.599 million per year after industry adjustments in price and output. Moreover, the Oregon rent decrease equal 60-70 percent of the sum of changes in producers' rents (Oregon and non-Oregon) and consumers' surpluses. Second, our highest estimates of Willamette Valley resident recreation benefits never exceeds 50 percent of our lowest estimate for the decrease in Oregon producer rents. When compared to the sum of all policy-induced changes in rents and surpluses, recreation-benefits never exceed 40 percent. In consequence, as clearly indicated by columns (5) and (6), even if resident outdoor recreationists were required to pay according to the full value of the benefits they receive

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Table V.1. Summary of Benefits and Costs of Alternative Open Field Burning Control Policies Under Various Assumptions and From Oregon and National Viewpoints (thousands of dollars)

| | | | | Implicit Total Costs | |
|---|---|---|---|---|---|
| Mobile Sanitizer Cost per Acre (1) | Decrease in Oregon Rents (2) | Decrease in "Sum" (3) | Resident Outdoor Recreation Benefits (4) | Oregon Viewpoint Col.(2)-Col.(4) (5) | National Viewpoint Col.(3)-Col.(4) (6) |
| Complete Ban | | | | | |
| $ 5 | $1,064 | $1,610 | $480 | $ 584 | $1,130 |
| | | | 249 | 815 | 1,361 |
| | | | 89 | 975 | 1,521 |
| 9 | 1,882 | 2,835 | 480 | 1,402 | 2,355 |
| | | | 249 | 1,633 | 2,586 |
| | | | 89 | 1,793 | 2,755 |
| 13 | 2,599 | 4,002 | 480 | 2,119 | 3,522 |
| | | | 249 | 2,350 | 3,753 |
| | | | 89 | 2,510 | 3,913 |
| Once in Three Years Burning | | | | | |
| 5 | 715 | 1,085 | 308 | 407 | 777 |
| | | | 160 | 555 | 925 |
| | | | 57 | 658 | 1,028 |
| 9 | 1,271 | 1,922 | 308 | 963 | 1,614 |
| | | | 160 | 1,111 | 1,762 |
| | | | 57 | 1,214 | 1,865 |
| 13 | 1,788 | 2,706 | 308 | 1,480 | 2,398 |
| | | | 160 | 1,628 | 2,546 |
| | | | 57 | 1,731 | 2,649 |
| Alternate Year Burning | | | | | |
| 5 | 536 | 816 | 213 | 323 | 603 |
| | | | 111 | 425 | 705 |
| | | | 40 | 496 | 776 |
| 9 | 960 | 1,453 | 213 | 747 | 1,240 |
| | | | 111 | 849 | 1,342 |
| | | | 40 | 920 | 1,413 |
| 13 | 1,365 | 2,276 | 213 | 1,152 | 2,063 |
| | | | 111 | 1,254 | 2,165 |
| | | | 40 | 1,325 | 2,236 |

Sources: Tables III.1 and IV.4

from control of open field burning, that amount could only partially compensate producers and/or consumers for their respective decreases in well-being.

The implication of these findings is obvious. For all field burning control policies investigated here, none can conceivably pass a benefit-cost test without a positive value being given the public good "improved visibility." Columns (5) and (6) of Table V.1 indicate our estimates of the net total costs of achieving the various improvements in Willamette Valley visibility associated with each field burning control policy. Of course, for a policy to pass the benefit-cost test, one must claim that the benefits of improved visibility associated with that policy equal or exceed the net total cost figures given in columns (5) and (6). Note that by adopting an insular Oregon viewpoint the benefits which must be claimed for improvements in visibility to pass a benefit-cost test are only 50-65 percent as large as those required from a national viewpoint. Consequently, one can easily conceive of a situation where from Oregon's viewpoint one or more policies pass benefit-cost tests which they fail if a national viewpoint is adopted. Moreover, this could occur even when improvements in air quality are valued more highly nationally than they are in Oregon.

In our opinion, however, the implicit total cost figures presented in columns (5) and (6) of Table V.1 do not place the implicit costs of each policy in particularly useful perspective. This is the case because those costs are not expressed relative to the population benefited or the benefits actually associated with each policy. Therefore, we now express the implicit costs of the visibility improvements associated with each policy per Willamette Valley resident and per mile of increased visibility per person. Such figures will indicate the minimum value that the benefits of improved visibility must assume per person or per person-mile for each policy to pass the standard benefit-cost test. Table V.2 reports these values in dollars per Willamette Valley resident per annun, while Tables V.3 and V.4 express the same values (in cents) as average and marginal costs of additional miles of minimum visibility per person-mile.*

Although it is a matter of opinion whether the values reported in Table V.2 are too high for any particular policy to pass a benefit-cost test, we are impressed with the considerable variation in the minimum values that the benefits of improved visibility must assume for policies to pass a benefit-cost test. On the other hand, it must be observed that the variation revealed in Table V.2 becomes unimportant for public policy formation if the minimum value placed on improved visibility is sufficiently high. For example, if the minimum value for improved visibility equals or exceed $4 per Willamette Valley resident, all policies except one would pass a benefit-cost test; only a ban on burning with mobile sanitizer costs at $13 per acre would fail.

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*Values in Table V.2 were obtained by dividing the implicit total costs of each policy (from columns (5) and (6) in Table V.1) by 680,000, the estimated population of the Willamette Valley. Implicit average costs in Tables V.3 and V.4 were calculated by dividing the implicit total costs of each policy by the total increases in pmv (from Table IV.2), while implicit marginal costs were found by dividing the increment in implicit total costs by the incremental change in pmv under each policy.

Table V.2. Implicit Total Costs of Improvements in Willamette Valley Minimum Daylight Visibility, by Viewpoint and Policy Under Various Assumptions (dollars per Willamette Valley resident)

| Mobile Sanitizer Cost per Acre | Outdoor Recreation Benefits | Strictly Oregon Viewpoint | | | National Viewpoint | | |
|---|---|---|---|---|---|---|---|
| | | Alternate Yr. Burning | Burning Once in Three Yrs. | Ban on Burning | Alternate Yr. Burning | Burning Once in Three Yrs. | Ban on Burning |
| $ 5 | High | $0.48 | $0.60 | $0.86 | $0.89 | $1.14 | $1.66 |
| | Median | 0.63 | 0.82 | 1.20 | 1.04 | 1.36 | 2.00 |
| | Low | 0.73 | 0.97 | 1.43 | 1.14 | 1.51 | 2.24 |
| 9 | High | 1.10 | 1.42 | 2.06 | 1.82 | 2.37 | 3.46 |
| | Median | 1.25 | 1.64 | 2.40 | 1.97 | 2.59 | 3.80 |
| | Low | 1.35 | 1.79 | 2.64 | 2.08 | 2.74 | 4.05 |
| 13 | High | 1.69 | 2.18 | 3.12 | 3.03 | 3.53 | 5.18 |
| | Median | 1.84 | 2.39 | 3.46 | 3.18 | 3.74 | 5.52 |
| | Low | 1.95 | 2.55 | 3.69 | 3.29 | 3.90 | 5.75 |

Source: Table V.1.

Table V.3. Implicit Average and Marginal Costs of Improvements in Willamette Valley Minimum Daylight Visibility, by Policy Under Various Assumptions and From a Strictly Oregon Viewpoint (cents per person-mile).

| Mobile Sanitizer Cost per Acre | Outdoor Recreation Benefits | Alternate Year Burning |  | Burning Once in Three Years |  | Ban on Burning |  |
|---|---|---|---|---|---|---|---|
|  |  | Average Cost | Marginal Cost | Average Cost | Marginal Cost | Average Cost | Marginal Cost |
| $ 5 | High | 1.34 | 1.34 | 1.18 | 0.81 | 1.08 | 0.91 |
|  | Median | 1.77 | 1.77 | 1.61 | 1.25 | 1.51 | 1.33 |
|  | Low | 2.06 | 2.06 | 1.91 | 1.56 | 1.81 | 1.62 |
| 9 | High | 3.11 | 3.11 | 2.80 | 2.08 | 2.60 | 2.25 |
|  | Median | 3.53 | 3.53 | 3.23 | 2.52 | 3.03 | 2.68 |
|  | Low | 3.83 | 3.83 | 3.53 | 2.84 | 3.32 | 2.97 |
| 13 | High | 4.79 | 4.79 | 4.30 | 3.15 | 3.93 | 3.28 |
|  | Median | 5.22 | 5.22 | 4.73 | 3.59 | 4.36 | 3.70 |
|  | Low | 5.51 | 5.51 | 5.03 | 3.90 | 4.65 | 3.99 |

Source: Tables IV.2 and V.1.

Table V.4. Implicit Average and Marginal Costs of Improvements in Willamette Valley Minimum Daylight Visibility, by Policy Under Various Assumptions and From a National Viewpoint (cents per person-mile).

| Mobile Sanitizer Cost per Acre | Outdoor Recreation Benefits | Alternate Year Burning | | Burning Once in Three Years | | Ban on Burning | |
|---|---|---|---|---|---|---|---|
| | | Average Cost | Marginal Cost | Average Cost | Marginal Cost | Average Cost | Marginal Cost |
| $ 5 | High | 2.28 | 2.28 | 2.05 | 1.29 | 1.90 | 1.64 |
| | Median | 2.67 | 2.67 | 2.44 | 1.64 | 2.29 | 2.03 |
| | Low | 2.94 | 2.94 | 2.71 | 1.87 | 2.56 | 2.30 |
| 9 | High | 4.69 | 4.69 | 4.26 | 2.78 | 3.97 | 3.45 |
| | Median | 5.08 | 5.08 | 4.65 | 3.12 | 4.36 | 3.84 |
| | Low | 5.34 | 5.34 | 4.92 | 3.36 | 4.64 | 4.15 |
| 13 | High | 7.80 | 7.80 | 6.33 | 2.49 | 5.94 | 5.24 |
| | Median | 8.19 | 8.19 | 6.72 | 2.83 | 6.32 | 5.61 |
| | Low | 8.49 | 8.49 | 6.99 | 3.07 | 6.59 | 5.89 |

Source: Table IV.2 and V.1.

Although the perspective provided by Table V.2 is informative, to an economist Tables V.3 and V.4 reveal the results of this study in a more useful fashion. There, we report the implicit average and marginal costs for improvements in Willamette Valley visibility per person-mile, by mobile sanitizer cost per acre, amount of recreation benefits, and field burning control policy.* In Table V.3 where we report implicit costs from a strictly Oregon viewpoint, person refers to Willamette Valley residents only, In contrast, in Table V.4 where we adopt a national viewpoint, the relevant population includes Willamette Valley residents and tourists.

Tables V.3 and V.4 are particularly valuable for two reasons. First, the implicit costs of field burning control policies are there expressed relative to the objective of such policies--namely, improvements in Willamette Valley visibility. Presumably rational policy evaluation is less difficult and less subject to error where the costs of alternative policies are expressed relative to the units of the objective desired. Again, one cannot objectively judge whether these costs are sufficiently high (low) that particular policies fail (pass) the standard benefit-cost test. Nevertheless, these cost estimates should at least put the values of visibility improvements required for policies to pass a benefit-cost test into proper perspective.

Second, Tables V.3 and V.4 reveal that improvements in Willamette Valley visibility are produced under conditions of decreasing average costs. The implications of this finding deserve special comment.

As is well known, for the attainment of an optimal allocation of resources, the marginal value (price) of outputs must everywhere equal marginal cost. If marginal value diverges from marginal cost, economic theory predicts that a reallocation of resources and some change in the output mix may increase economic well-being. (For present purposes, we may safely and conveniently ignore the myriad qualifications that welfare economists have found to apply to these propositions.) Application of the marginal cost pricing rule creates a dilemma under conditions of decreasing costs, however. By setting price equal to marginal cost, economic efficiency is achieved but the operation would run at a deficit. By setting price equal to average cost and thereby avoiding a deficit, economic welfare would not be maximized because price would exceed marginal cost. Proposed solutions to this dilemma include (a) setting price equal to marginal cost and financing the deficit out of general tax revenues, (b) setting the marginal unit's price equal to marginal cost and charging discriminatory non-uniform infra-marginal prices, (c) setting price equal to marginal cost and charging a once-only (or possibly annual) lump sum amount for the right to purchase at the marginal-cost-determined price, as well as variations on these three. Note that each of these solutions involve special non-market arrangements; under decreasing cost conditions, additional taxation, price discrimination, creation of exclusive groups, and other devices are required to achieve a welfare-maximizing solution.

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*Since the alternate-year burning policy improves visibility least among the three policies, average and marginal costs for that policy must be assumed equal.

The relevance of the preceding remarks for the evaluation and selection of the optimal open field burning control policy in the Willamette Valley is as follows. It is commonly believed that if air quality (here measured by minimum daylight visibility) was not a public good and, hence, could be valued and sold in some fashion comparable to private goods, or if transactions and bargaining costs plus institutional arrangements did not preclude negotiations between air pollutors (here seed growers) and pollutees (here Valley residents and tourists), no public policy regulating polluting activities (here open field burning) would be necessary. Moreover , public decisions which generate benefits and losses to different groups (here seed growers, consumers, Valley residents, and tourists) could be avoided. Although satisfaction of the stated conditions would undoubtedly eliminate these public policy problems in numerous situations, satisfaction of neither condition would obviate the need for a public policy with respect to open field burning. Since improvements in visibility are produced under conditions of decreasing costs, the optimal level of visibility would necessarily be associated with revenues too small to compensate growers and consumers if visibility "sold" at a uniform infra-marginal price. In contrast, at non-optimal levels of visibility, there would be inefficiency and (unless price equalled average costs) a deficit or surplus to be "managed." In either hypothetical case, decreasing costs would be sufficient to recreate a public policy problem with respect to open field burning, and special arrangements involving government coercion and discrimination among various groups would be required to achieve a welfare-maximizing solution. Consequently, the problems associated with open field burning are of public concern for more reasons than are generally appreciated.

In conclusion, we remind the reader of a very simple point. Although the marginal value of improved visibility in the Willamette Valley is unknown, reasonable estimates can and have been made of the implicit values that such improvements must assume for alternative open field burning control policies to pass standard benefit-cost tests. (see Tables V.2, V.3, and V.4). Given such information, a welfare-maximizing solution to the field burning problem in the Willamette Valley reduces itself to specifications of (a) a reasonable minimum value for improved visibility and (b) the relative desirability of alternative methods (including doing nothing) to distribute equitably the gains and losses under the selected policy. Following tradition, we suggest that these specifications are appropriately made in the political arena.

# APPENDIX A

## NOTES ON TWO-SECTOR GENERAL EQUILIBRIUM MODELS OF PRODUCTION AND DISTRIBUTION

This appendix develops materials that underlie the general equilibrium model presented in the main text of this report. Some of the materials are standard fare in economic textbooks, while others are new. In either case, however, numerous propositions and relationships asserted in the main text are derived and/or explained here.

The first section of the appendix provides brief derivations of possible production and distribution situations in two-sector general equilibrium models, initially for an economy with no intermediate goods and then for an economy with inter-industry flows of materials. The definitions and assumptions on which our later analysis relies are stated in this first section. In the second section techniques are developed to analyze the impact of changes in factor supply and technology on production possibilities. This section is fundamental because pollution control policies often involve such changes. The third section concludes the appendix by specifying the impact of technological external diseconomies on production possibilities. The derivation reported there is new.

### A.1 Fundamental Production and Income Distribution Possibilities

This section presents production and income distribution possibilities in a two-sector general equilibrium model where factor supplies and production technology are fixed.* Figure A.1 shows the usual Edgeworth-Bowley production box diagram. The vertical sides of the box $(OO_X = O'O_Y)$ measures the economy's fixed supply of capital, while the horizontal sides of the box $(OO_Y = O'O_X)$ measure its supply of labor. Isoquants for X are drawn with reference to $O_X$, and the isoquants for Y are drawn with reference to $O_Y$. The tangency points of the two sets of isoquants trace out the efficiency locus $O_XQO_Y$. The efficiency locus indicates the alternative factor allocations between X and Y which maximize the output of either good given the output of the other good.

Assuming both production functions are homogeneous of the first degree (i.e., constant returns to scale), the outputs of X and Y can be measured for any point in the box by the distances cut off by the appropriate isoquants along any ray from theorigins $O_X$ and $O_Y$. The diagonal

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*The following derivation of the production possibility curve in the Edgeworth-Bowley production box diagram uses the technique developed by K. M. Savosnick, *"The Box Diagram and the Production Possibility Curve,"* Ekonomisk Tidskrift, Vol, 60, No. 3 (September 1958), pp. 183-97.

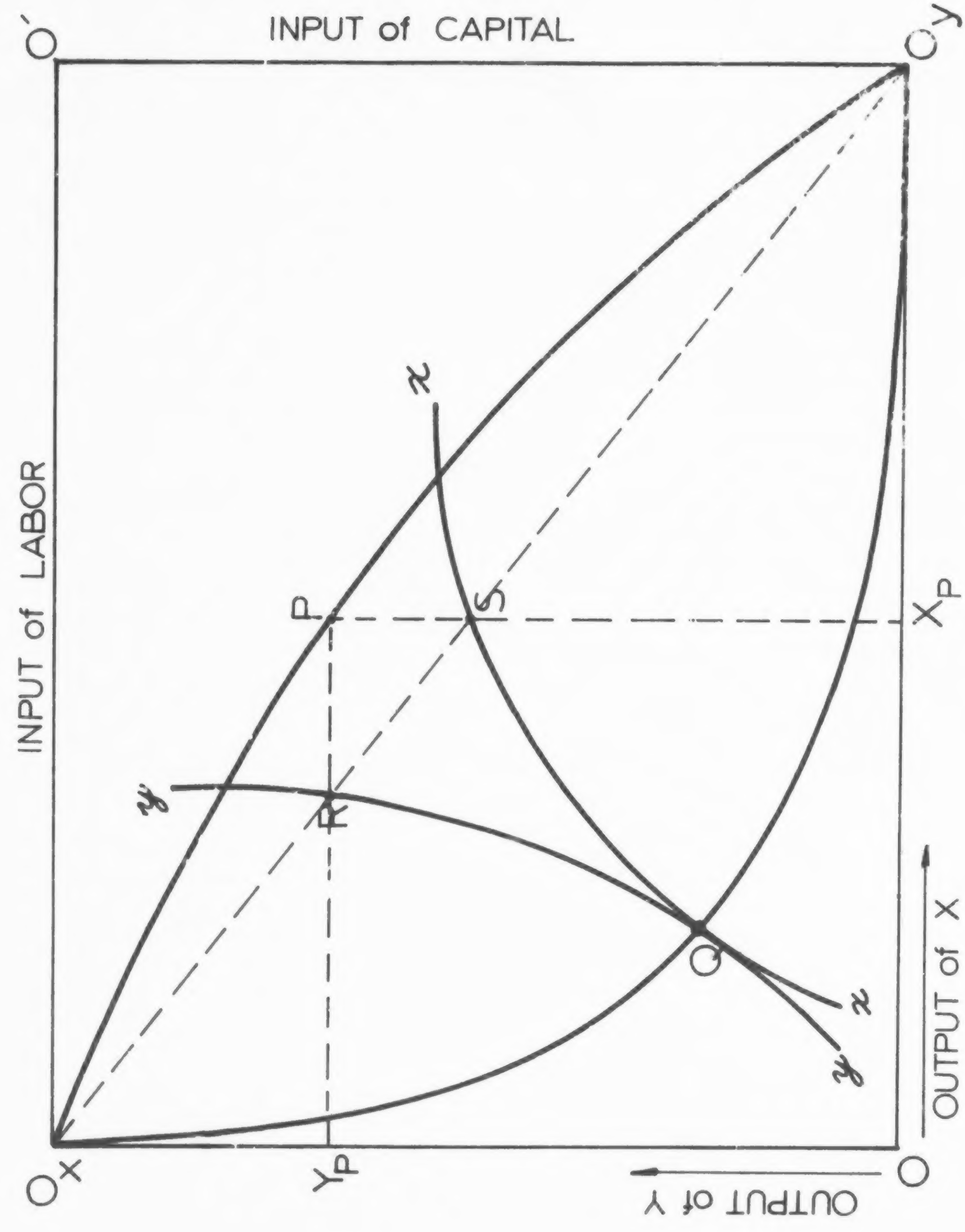
O'
INPUT of CAPITAL
$O_y$
INPUT of LABOR
P
S
$X_P$
x
x
y
y
R
Q
$O_x$
$Y_P$
O
OUTPUT of X
OUTPUT of Y

FIGURE A.1

of the box, $O_XO_Y$, provides a convenient common ray through both isoquant maps. Therefore, the output of X at point Q on the efficiency locus is measured here by the distance $O_XS$ cutoff on the diagonal by the isoquant xx, while the output of Y at Q is measured by $O_YR$ cut off on the diagonal by isoquant yy. Furthermore, given constant returns to scale, the ratios $O_XS/O_XO_Y$ and $O_YR/O_XO_Y$ indicate the respective proportions of the economy's maximum possible outputs of X and Y produced at Q.

By projecting vertically from S to the horizontal axis $OO_Y$, the output of X at Q would be $OX_P$ measured in units such that the economy's maximum possible production of X is $OO_Y$. Similarly, by projecting horizontally from R to the vertical axis $OO_X$, the output of Y at Q would be $OY_P$ measured in units such that the economy's maximum possible output of Y is $OO_X$. Consequently, point P is the point on the economy's production-possibility, or transformation, curve corresponding to point Q on the production efficiency locus. Of course, by plotting in similar fashion the output combinations associated with all points on the efficiency locus $O_XQO_Y$, one would obtain the complete production possibility, or transformation, curve $O_XPO_Y$ with reference to the origin O.

Thus, there is a one-to-one corresondence between the production-efficiency locus and the production-possibility curve. For every efficient input combination there is an output combination on the production-possibility curve, and vice versa. This fact will prove useful later in our analysis.

We next develop the income distribution relationship in this model. Assuming perfectly competitive factor and product markets, the factor-price ratio at point Q in Figure A.2 would equal the identical marginal rates of substitution between capital and labor in both industries, i.e., the slope of the isoquants at point Q. Therefore, the value of capital measured in units of labor can be obtained by constructing the line $O_YM$, with the same slope as the isoquants at Q, to intersect $O_XO'$ extended to M. The distance $O_XM$ indicates national income at P measured in units of labor, $O_XO'$ representing the income of labor in terms of labor and O'M representing the income of capital in terms of labor. By projecting vertically from M to N on $OO_Y$ extended, the income distribution relationship is transferred to the horizontal axis. In turn, by drawing OP, PN, and $WO_Y$ (parallel to PN), OP is divided into two segments OW and WP (=OI) representing the shares of output at P being received by labor and capital, respectively.

Points W and I are reference, as opposed to actual consumption, points. Labor's (capital's) income is a budget line through W(I), with reference to origin O, with slope equal to the tangent to the transformation curve at P. Under competitive conditions, of course, the slope of a tangent to the production-possibility curve indicates relative commodity prices.

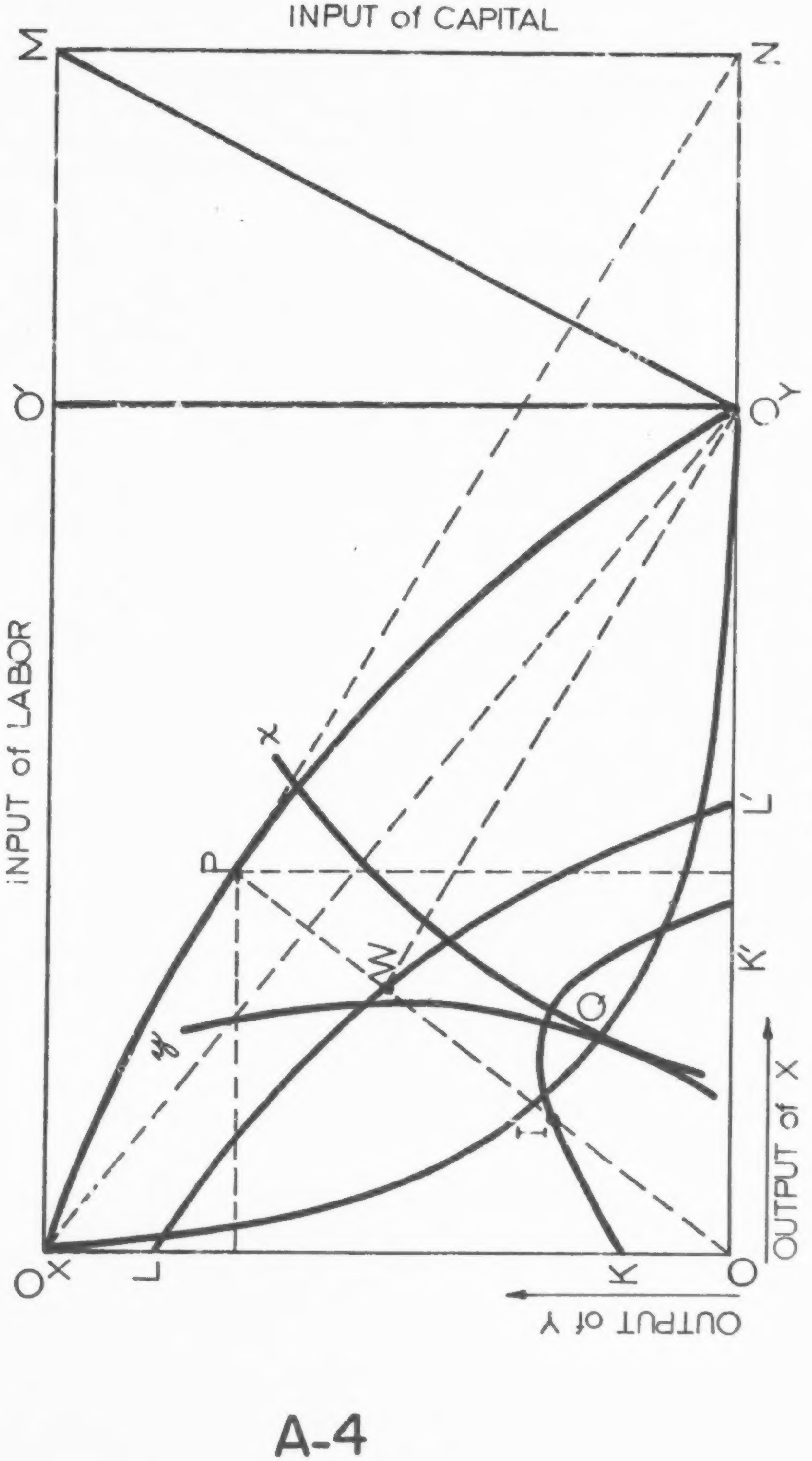
INPUT of CAPITAL
M
N
O'
O_Y
INPUT of LABOR
x
P
W
Q
y
I
L
L'
K
K'
O_X
O
OUTPUT of X
OUTPUT of Y

FIGURE A. 2

A-4

By repetition of the above procedure one obtains the income distribution curves for labor and capital, LWL' and KIK', repectively. These curves establish the location of the budget lines for labor and capital as the intersection of rays from the origin O tc the relevant point on theproduction-possibility curve. Since X is the capital-intensive commodity, capital's (labor's) share of output increases (decreases) as the economy increases the output of X.

Next consider an economy with two outputs, X and Y, each of which uses the two primary factors, capital and labor, and the output of the other industry as inputs.* The productive capacity of the economy is defined by

$$X = x(L_x, K_x) - a_1 \cdot y\ (L_y, K_y)$$

$$Y = -a_2 \cdot x\ (L_x, K_x) + y(L_y, K_y)$$

$$L_o = L_x + L_y$$

$$K_o = K_x + K_y$$

where X and Y are final goods and $a_1$, $a_2$ are fixed coefficients representing respectively the requirements of X for producing Y and of Y for producing X.

If there were no inter-industry flows, i.e., $a_1$ and $a_2$ were assumed equal to zero, and if the production functions for X and Y were homogeneous of degree one, then the usual production-possibility curve between X and Y could be derived from a production box diagram as in the previous section. Suppose such a derivation would result in the curve $O_X PO_Y$ in Figure A.3. However, if $a_1$ and $a_2$ do not equal zero, then $O_X PO_Y$ does not apply. Instead, with each output also serving as an input for the other output, the true production possibilities for X and Y are within the area $OO_X PO_Y$.

This curve may be obtained in the following fashion. Construct a set of new axes PD and PH originating at P. Construct lines PE and PG such that their slopes with respect to PD and PH express the fixed requirement of one output per unit of the other, i.e., $a_1$ and $a_2$ respectively. The intersections PE and PG with the original axes indicate the coordinates of point P', corresponding to P, and express the maximum outputs of X and Y available for consumption (and/or trade) in an economy where inter-industry flows described by $a_1$ and $a_2$ hold. Of course, repetition of this procedure for all points on the ZPZ' segment of $O_X PO_Y$ permits construction

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*This model is due to Vanek. See J. Vanek, *Variable Factor Proportions and Inter-Industry Flows in the Theory of International Trade,* Quarterly Journal of Economics, February 1963, pp. 129-142.

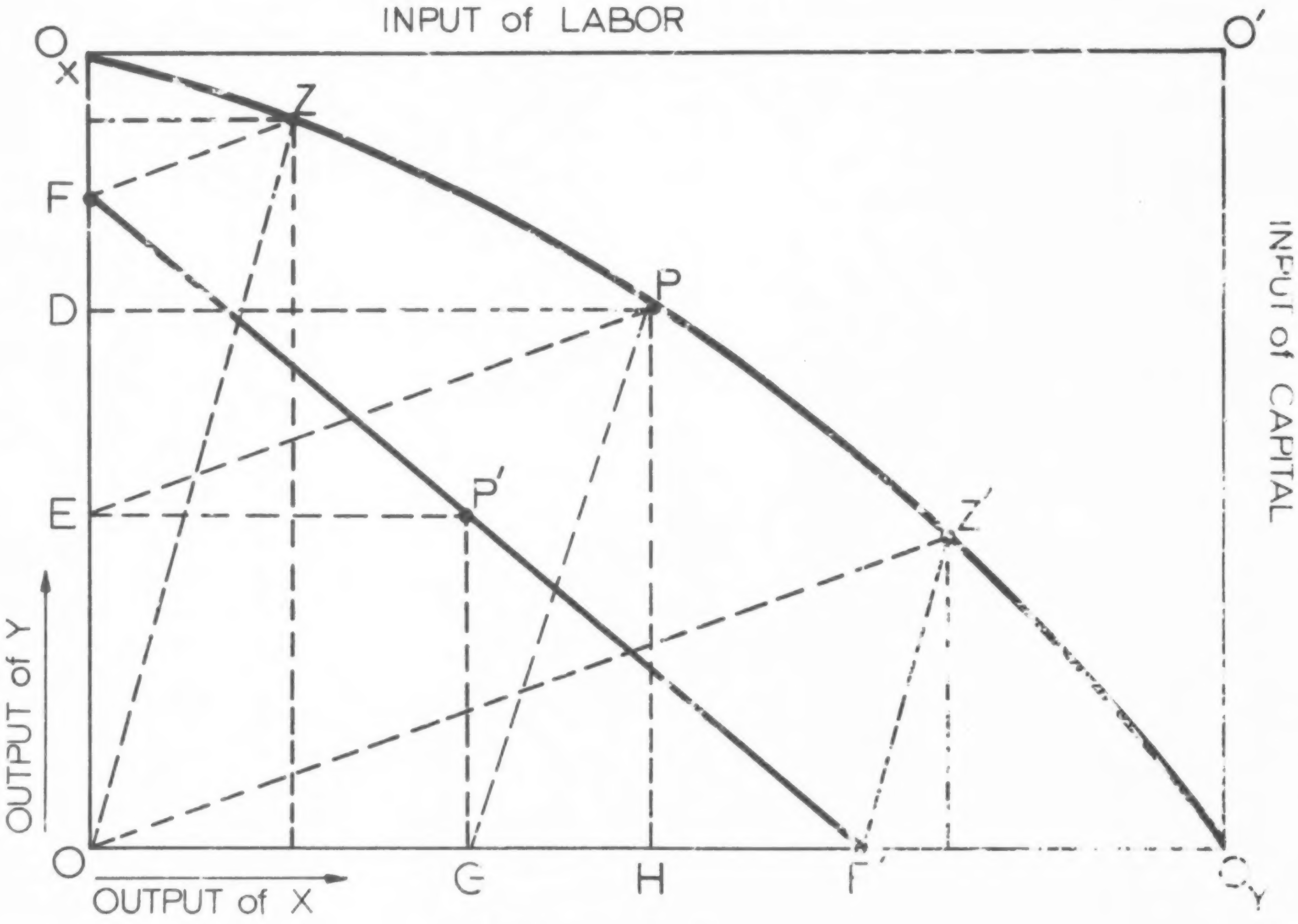
INPUT of LABOR
INPUT of CAPITAL
OUTPUT of Y
OUTPUT of X
$O_X$
$O'$
$O_Y$
O
Z
Z'
P
P'
F
F'
D
E
G
H

FIGURE A.3

of the net output for consumption without trade curve FP'F'. In the absence of trade, segments $O_XZ$ and $O_YZ'$ on the gross output curve represent unattainable outputs because the required inputs are not available. For example, at Z the total output of X is absorbed in the production of Y (OZ is parallel to GB), and any attempt to increase the output of Y would simultaneously increase the intermediate demand for X and reduce the quantity of X, and hence Y, produced. (A similar argument holds at the other end of $O_XPO_Y$.) However, with trade in intermediate goods possible, whenever the world terms of trade are smaller (larger) in absolute value than slope of the tangent to FP'F' at F(F'), the attainable level of final demand for Y(X) lies somewhere beyond F on the Y-axis (F' on the X-axis) and depends on world terms of trade.*

Points on FP'F' (such as P') indicate net outputs for final demand, while their corresponding points on ZPZ' (such as P) indicate gross outputs in the economy. Consequently, where inter-industry flows exist, the income distribution relationship is appropriately expressed with reference to the net output production-possibility curve FP'F'. The procedure followed in deriving the income distribution curves for labor and capital, LWL' and KIK', respectively, in Figure A.4 differs from the procedure presented in the previous section in only one respect: lines were drawn northwest from N (and from $O_Y$ parallel to lines from N) to points on the net (or opposed to the gross) production possibility curve. Rather than reproduce our earlier derivation verbatim, we merely label Figure A.4 identically to Figure A.3 so that our previous derivation applies equally well to the situation reported in Figure A.4. (Of course, with trade capital's and labor's maximum (minimum) shares of output could exceed those indicated by the endpoints of KIK' and LWL'. The precise maximum would depend on world terms of trade.)

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*For a full discussion of these matters, see Stephen E. Guisinger, *Negative Value Added and the Theory of Effective Protection*, Quarterly Journal of Economics, LXXXIII (August 1969), pp. 415-433.

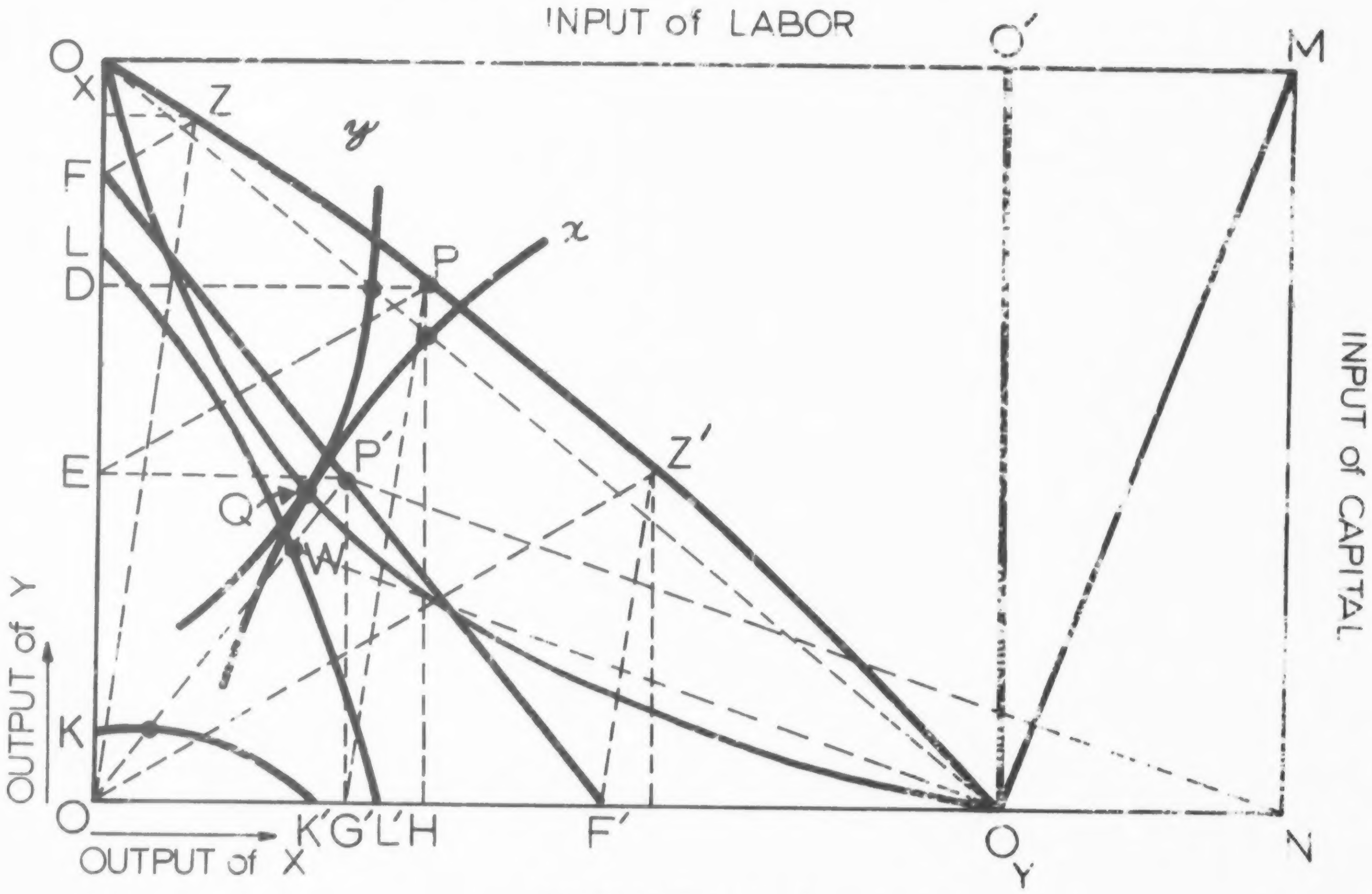
INPUT of LABOR
O′
M
$O_X$
Z
y
F
x
L
P
D
x
E
P′
Z′
Q
W
INPUT of CAPITAL
OUTPUT of Y
K
O
K′G′L′H
F′
$O_Y$
N
OUTPUT of X

FIGURE A.4

## A.2 Changes in Factor Supply and Technology*

Consider first the case of a reduction in the supply labor. Its effect would be to reduce the size of the production box diagram and shift the efficiency and production-possibility loci toward the origin. For example, Figure A.5 reproduces the production box diagram $OO_XO'O_Y$ and production possibility curve $O_XPO_Y$ presented in Figure A.1. With a reduction in labor supply, the size of the box decreases to $OO_XO^*O_Y^*$ and the efficiency locus becomes $O_XQ^*O_Y^*$. To determine the new production-possibility curve, we once again measure outputs by distances cut off by isoquants along rays projected from the isoquant map origins, now, $O_X$ and $O_Y^*$. Outputs are no longer measured by distances on the production box diagonal, however. Instead, outputs are measured along rays with identical slopes from origins $O_X$ and $O_Y^*$. To do otherwise would alter the units in which outputs of X and Y were originally measured. In Figure A.5, rays $O_XS^*M^*$ and $O_Y^*R^*N^*$ have identical slopes equal to the slope of $O_XO_Y$ amd serve the purpose originally fulfilled by the diagonal $O_XO_Y$. (The diagonal of the new box serves no useful purpose and, therefore, is not indicated in Figure A.5.)

If the economy devoted its entire resource endowment to the production of X, it would operate on isoquant $x_M^*$ at $O_Y^*$. Therefore, maximum attainable output of X would be measured by the distance $O_XM^*$ cut off by $x_M^*$ on the ray $O_XO_Y$, while the output of Y would be zero. By projecting vertically from $M^*$ to the horizontal axis, the output of X at $O_Y^*$ would be $OX_M^*$ measured in units such that the economy's previous maximum possible output of X is $OO_Y$. Similarly, if the economy maximized its output of Y, it would operate on isoquant $y_N^*$ at $O_X$ and the maximum output of Y is obtained by projecting horizontally from $N^*$ to the vertical oxis. By employing ray $O_Y^*N^*$ to measure output of Y, the maximum possible output of Y, $OY_N^*$, is measured in the same units before and after the reduction in labor supply.

Finally, consider the outputs of X and Y associated with the $Q^*$ allocation of factor supplies. The output of X at point $Q^*$ is measured by the distance $O_XS^*$ on ray $O_XM^*$, while the output of Y is measured as $O_Y^*R^*$ on ray $O_Y^*N^*$. Projecting vertically and horizontally as before, the outputs of X and Y at $Q^*$ would be $OX^*$ and $OY^*$, respectively, and $P^*$ is the point on the economy's new production-possibility curve corresponding

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*For expositional simplicity only, in this and the following section we derive shifts in production possibility curves for economies with no inter-industry flows of materials. Since the procedures developed in the previous section to deal with inter-industry relations can easily and obviously be applied in situations analyzed in this and the following section, there would appear little reason to complicate the presentation of new analytical results needlessly.

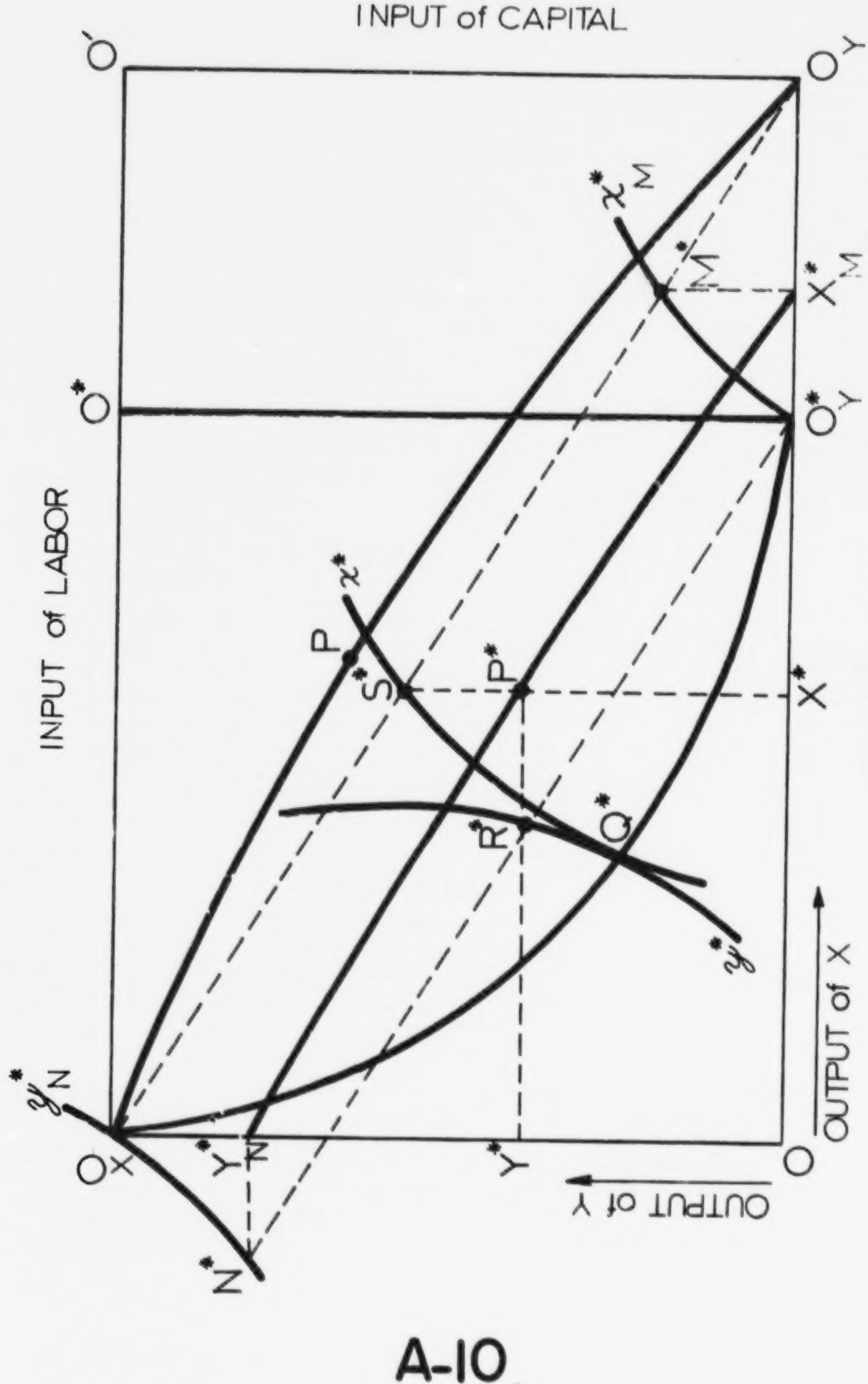
INPUT of CAPITAL
INPUT of LABOR
O'
O*
$O_Y$
$O^*_Y$
$X^*_M$
$M^*$
$x^*_M$
P
$P^*$
$S^*$
$x^*$
$X^*$
$R^*$
$Q^*$
$y^*$
$y^*_N$
$O_X$
$Y^*_N$
N
$Y^*$
O
$N^*$
OUTPUT of X
OUTPUT of Y

FIGURE A.5

to point Q* on its new production efficiency locus. Moreover, by plotting in a similar manner the outputs associated with all points on the efficiency locus $O_XQ^*O_Y^*$, the complete new production-possibility curve $Y_M^*P^*X_M^*$ would be obtained.

Of course, the above technique can be applied to all conceivable changes in factor supply in our simple two-factor-two-commodity general equilibrium model. To support this view, Figure A.6 is labelled identically to Figure A.5 but shows the shift in the production-possibility curve following a simultaneous decrease in labor supply and increase in capital supply. The derivation of the new production-possibility curve $Y_N^*P^*X_M^*$ would be obtained.

Of course, the above technique can be applied to all conceivable changes in factor supply in our simple two-factor-two-commodity general equilibrium model. To support this view, Figure A.6 is labelled identically to Figure A.5 but shows the shift in the production-possibility curve following a simultaneous decrease in labor supply and increase in capital supply. The derivation of the new production-possibility curve $Y_N^*P^*X_M^*$ would follow the procedure developed in the preceding paragraphs.

Continuing to assume production functions are homogeneous of the first degree and ignoring consideration of production technologies requiring intermediate goods, we now specify the impact of production process changes to reduce pollution on an economy's production-efficiency locus and production-possibility curve. The technique presented here is new. Nowhere in the literature is the impact of technical progress (positive or negative) on production-possibilities specified in a fashion comparable to the technique developed by Savosnick to derive the production-possibility curve from the production-efficiency locus. Although the following analysis concentrates on the "negative technical progress" associated with production process changes to reduce pollution, the techniques presented are obviously and easily applicable in situations where there is positive technical progress. Similarly, although the analysis deals only with changes in the production function for X, our results are equally applicable to changes in the production function for Y.

Production process changes to reduce pollution can be classified in a fashion similar to that employed by Hicks to classify (positive) technical progress.* Production process changes to reduce pollution would consist of changes in production functions such that more input(s) are required to produce any given level of output, i.e., negative technical progress. Such changes are classified here as neutral, capital-using, or labor-using according to their effect on the marginal productivities of capital and labor. A neutral change would be one which reduces the marginal productivities of both factors in the same proportion. A capital-using change would

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*J. R. Hicks, *The Theory of Wages*, McMillan & Co. (London), 1932, p. 131ff.

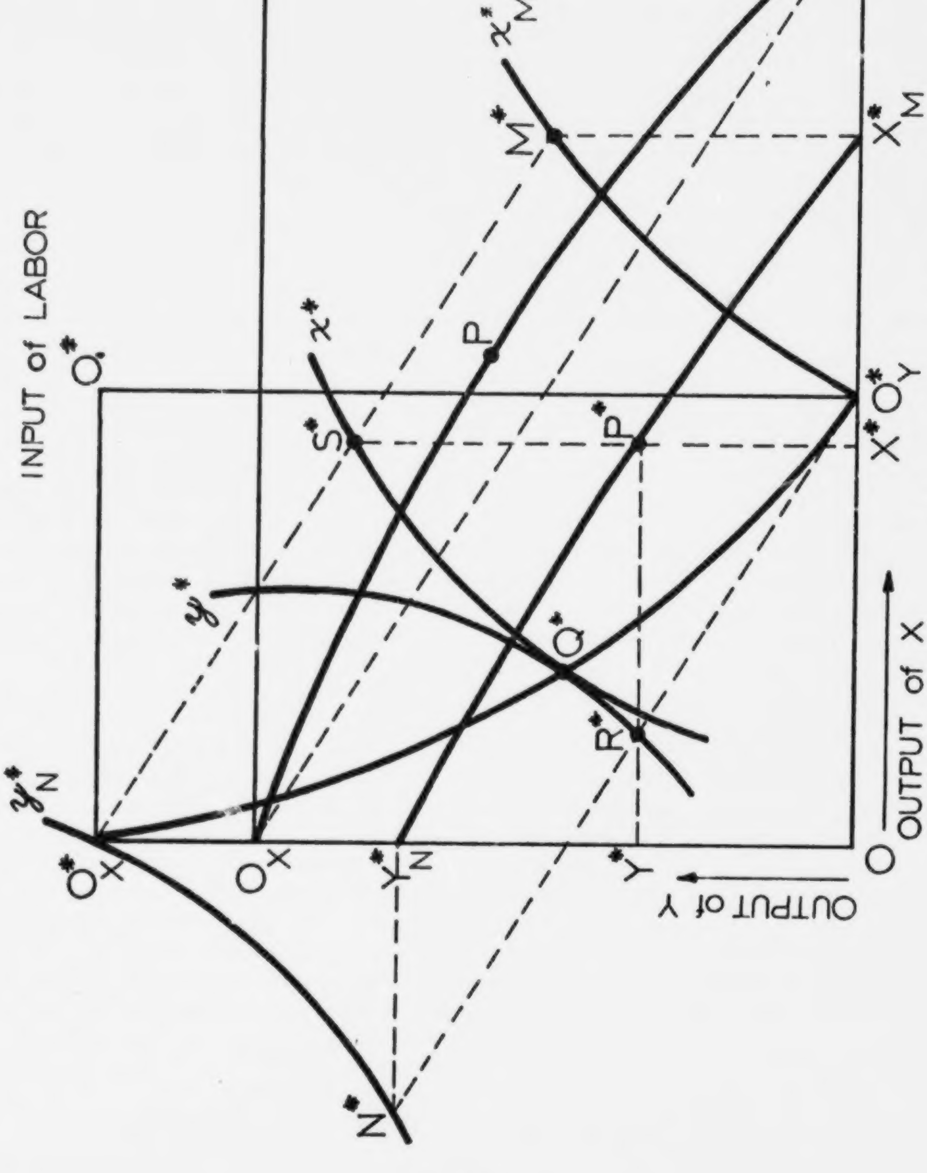

INPUT of CAPITAL
INPUT of LABOR
O'
$O^*$
$O_Y$
$x^*_M$
$M^*$
$X^*_M$
P
$x^*$
$S^*$
$P^*$
$X^*O^*_Y$
$y^*$
$Q^*$
$R^*$
$y^*_N$
$O^*_X$
$O_X$
$Y^*_N$
$Y^*$
O
OUTPUT of X
OUTPUT of Y
$N^*$

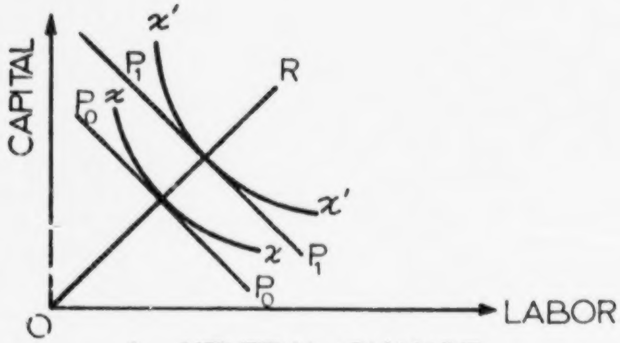
FIGURE A.6

**A-12**

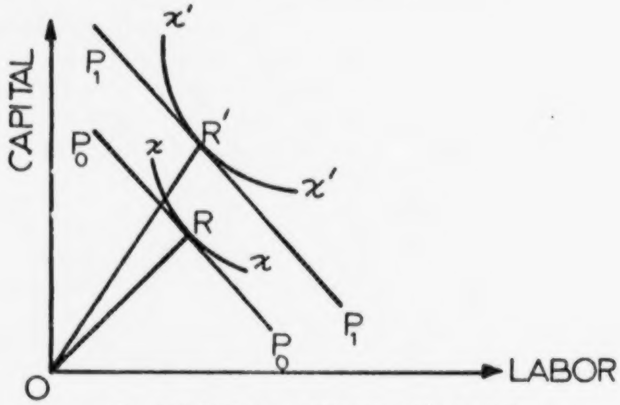
reduce the marginal productivity of capital less than the marginal productivity of labor. A labor-using process change would reduce the marginal productivity of capital more than the marginal productivity of labor. Each of these changes is depicted in Figure A.7, where isoquants xx and x'x' indicate alternative combinations of capital and labor required to produce some given level of X before and after a production process change to reduce pollution. With given relative factor prices ($P_1P_1$ i.e. parallel to $P_oP_o$), a neutral production process changes would not change the capital-labor ratio employed to produce X, whereas a capital-using (labor-using) process change would increase (decrease) the capital-labor ratio.

With definitional matters completed, the analysis of production process changes may begin. Consider first the case of a neutral production process change in the X industry. Its effect is to shift X isoquants uniformly proportionately away from their origin, $O_X$, thereby reducing the outputs associated with the set of original isoquants proportionately, say m percent. For this reason, a neutral change produces no change in the production-efficiency locus in Figure A.8, although it does produce an m percent decline in the output of X associated with each possible efficient factor allocation between X and Y. Consequently, outputs of X are no longer appropriately measured along the diagonal $O_XO_Y$ but rather along the ray $O_XM$, where OM = (1-m)($OO_Y$), or the maximum possible output of X following the postulated neutral production process change to reduce pollution. Measuring along $O_XM$, the output of X at Q on the efficiency locus is now measured by the distance $O_XS'$, where S' lies on $O_XM$ at the intersection of a horizontal projection from S. Projecting vertically from S', the output of X at Q would now be OXp', which equals (1-m)(OXp). Consequently, point P' is the point on the economy's production-possibility curve corresponding to point Q on the production-efficiency locus after the postulated neutral production-process change, and the new production-possibility curve would be $O_XP'M$. (Note that X and Y continue to be measured in the same units and with reference to the origin O.)

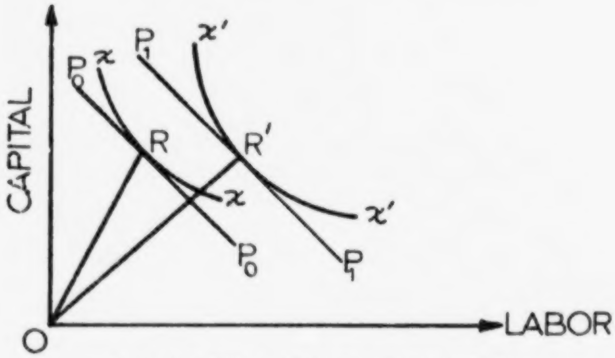
Next, the impact of a labor-using production process change in X to reduce pollution is specified with the aid of Figure A.9. As before, $O_xQO_Y$ and $O_XPO_Y$ represent the original production-efficiency locus and production-possibility curve, respectively, and yy, xx, and $x_mx_m$ are typical isoquants of production functions with homogeneity of degree one. A shift to a labor-using production process in X would shift the production-efficiency locus from $O_XQO_Y$ to $O_XQ'O_Y$, and the maximum possible output of X would decline from $OO_Y$ (that output associated with isoquant $x_mx_m$) to OM (that output associated with isoquant $x'_mx'_m$). With a labor-using, linearly homogeneous production function, outputs of X can again be measured along the ray $O_XM$ because there would necessarily be equal proportionate reductions in the output obtained from any factor combination. Thus, the output of X at Q' on the new production-efficiency locus would be measured by the distance $O_XS'$, where S' lies at the intersection of a horizontal projection from T (where x'x' cuts the diagonal). Consequently, projecting vertically from S', the output of X at Q' is determined to be OXp' and point P' lies on the economy's new production possibility curve $O_XP'M$.


CAPITAL
$x'$
$P_1$
R
$P_0$
$x$
$x'$
$x$
$P_1$
$P_0$
O
LABOR

A. NEUTRAL CHANGE


CAPITAL
$x'$
$P_1$
$P_0$
$x$
$R'$
$x'$
R
$x$
$P_1$
$P_0$
O
LABOR

B. CAPITAL USING CHANGE


CAPITAL
$P_0$
$x$
$P_1$
$x'$
R
$R'$
$x$
$x'$
$P_0$
$P_1$
O
LABOR

C. LABOR USING CHANGE

FIGURE A.7 PRODUCTION PROCESS CHANGES TO REDUCE POLLUTION

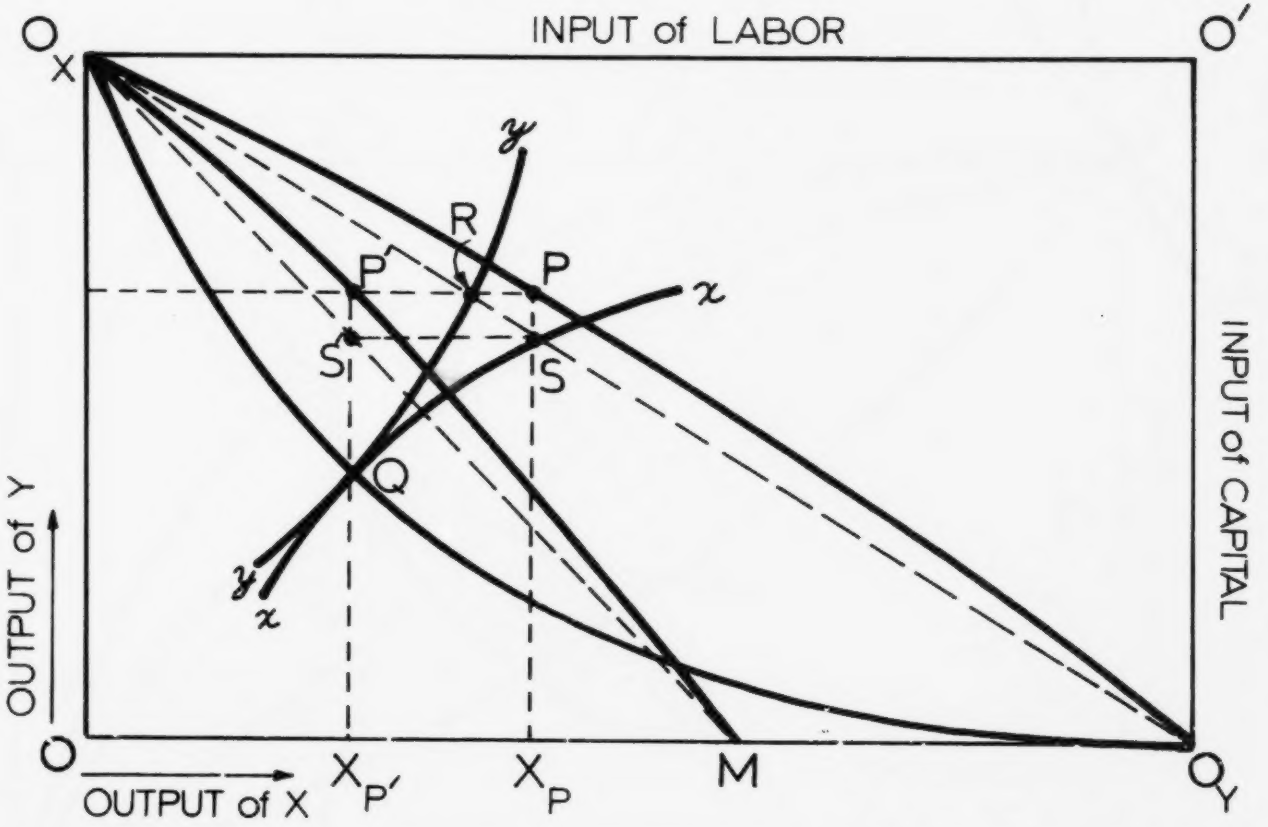

$O_X$
INPUT of LABOR
$O'$
y
R
$P'$
P
x
$S'$
S
Q
y
x
INPUT of CAPITAL
OUTPUT of Y
O
OUTPUT of X
$X_{P'}$
$X_P$
M
$O_Y$

FIGURE A.8 SHIFT IN PRODUCTION - POSSIBILITY CURVE WITH NEUTRAL PRODUCTION PROCESS CHANGE IN X TO REDUCE POLLUTION

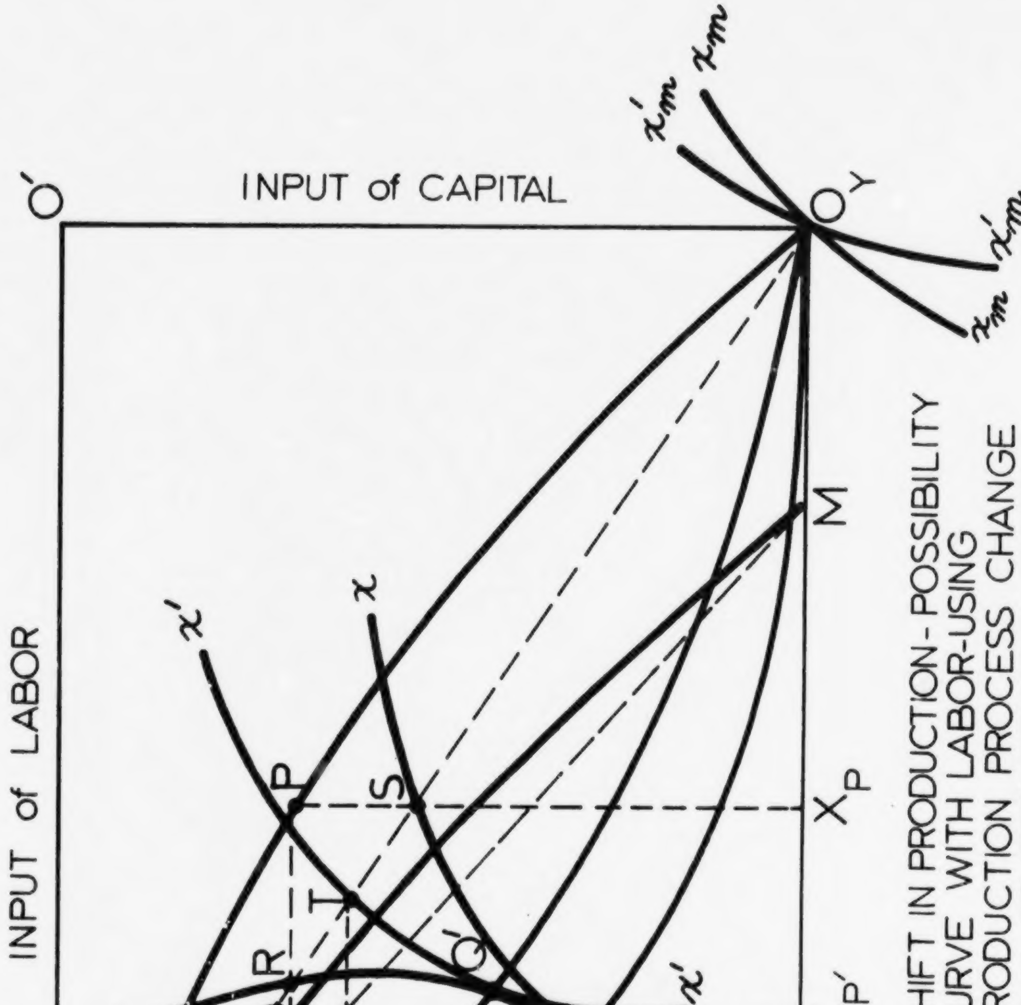

O'
INPUT of CAPITAL
O_Y
x_m
x'_m
x'_m
x_m
INPUT of LABOR
x'
x
P
S
T
R
Q'
P'
S'
y
x'
Q
x
M
X_P
X_P'
O_X
Y_P
O
OUTPUT of Y
OUTPUT of X

FIGURE A.9 SHIFT IN PRODUCTION-POSSIBILITY CURVE WITH LABOR-USING PRODUCTION PROCESS CHANGE IN X TO REDUCE POLLUTION

Finally, Figure A.10 specifies the new production possibility curve $O_X P'M$ that our model economy would face following a capital-using production process change in X that shifts the production-efficiency locus toward the origin O. Figure A.10 is labelled identically to Figure A.9 and the derivation of the new production-possibility curve $O_X P'M$ would precisely parallel the derivation given in the preceeding paragraph.

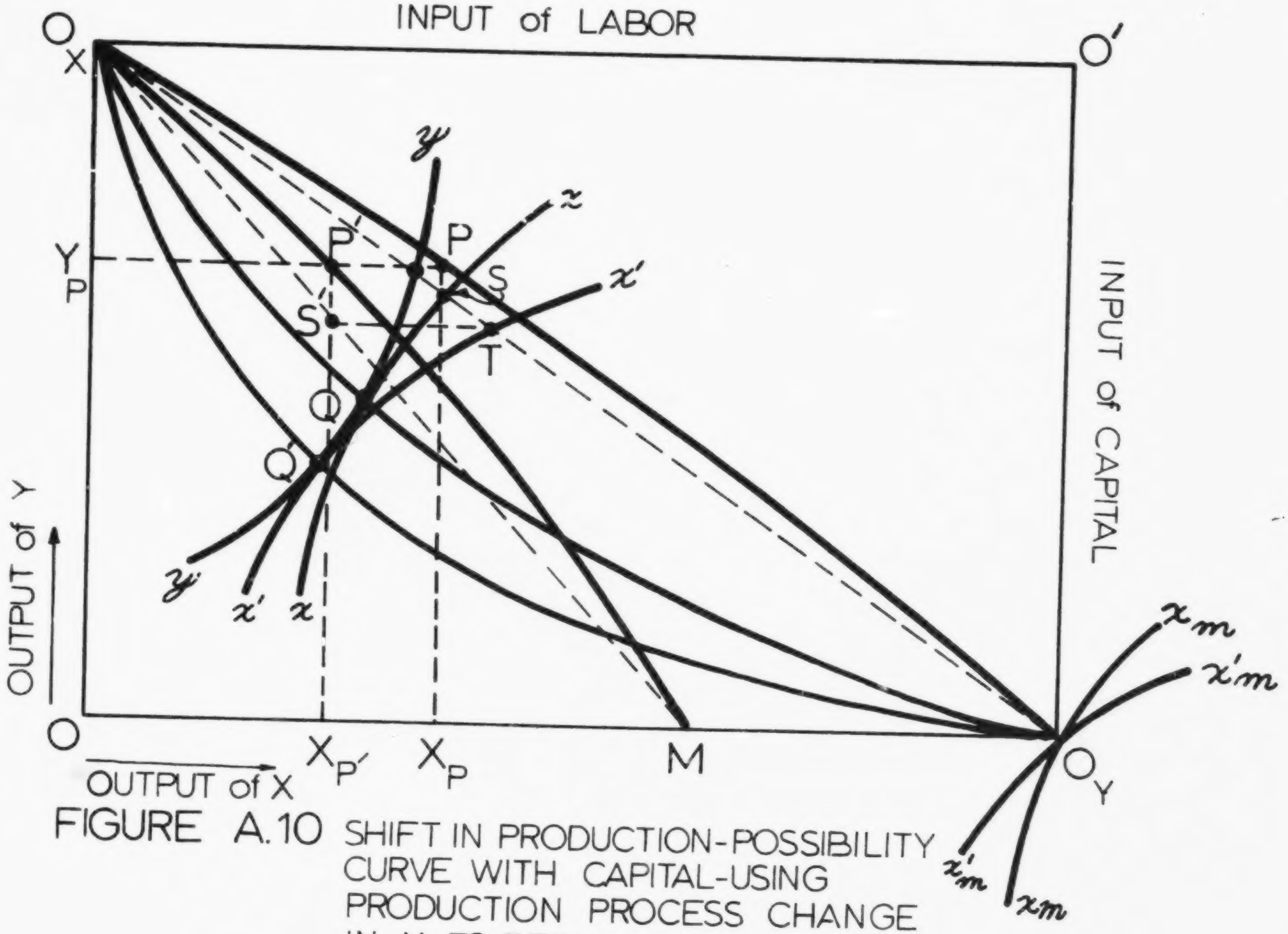

INPUT of LABOR
O
X
O'
INPUT of CAPITAL
Y
P
y
z
x'
P'
P
S
S'
T
Q
Q'
y'
x'
x
OUTPUT of Y
O
OUTPUT of X
X
P'
X
P
M
O
Y
x m
x' m
x' m
x m

FIGURE A.10 SHIFT IN PRODUCTION-POSSIBILITY CURVE WITH CAPITAL-USING PRODUCTION PROCESS CHANGE IN X TO REDUCE POLLUTION

## A.3 Technological External Diseconomies and Production Possibilities

Firms in a competitive industry may impose Pareto-relevant or technological external diseconomies on (1) other firms in the same industry and/or (2) firms in other industries through their influence on technological production relationships, as well as on (3) consumers, and thereby themselves and other firms, through their influence on the "state of the environment." The effects of productive activity on the state of the environment is discussed in detail in the main text of this report. Here we specify the direct impact of technological external diseconomies on production possibilities. Although the technique presented here is new, it applies our extension of Chipman's concept of "parametric externalities" and the technique developed in the previous section to examine negative technical progress.* Consideration is given to both output- and input-generated external diseconomies.

Though other specifications of technologically relevant external diseconomies are possible, our extension of Chipman's concept of parametric external economies of scale to cover external diseconomies is particularly convenient because a production possibility curve can be derived rather easily despite the complexities created in simple economic models by external diseconomies. Our concept of external diseconomies is as follows. Each entreprenuer in a competitive industry is assumed to act as if his firm has constant returns to scale, and departures from this constant factor-output relationship are regarded by him as the result of perturbations in his unit-homogeneous production function (even where such disturbances are partly caused by changes in his own firm's output and/or factor usage). Such shifts in production functions are assumed to be related to the levels of aggregate industry output and/or factor employment. From this viewpoint, parametric external diseconomies generate negative technical progress within an industry, or for some other industry (or industries), that is directly related to its output and/or factor employment. Where previously we examined once-only negative changes in technology, we now consider successively increasing negative technical changes directly related to its own or some other industry's output and/or factor usage.

Consider first neutral parametric external diseconomies in the X industry that depend on the output of X. Its effect would be to shift X isoquants uniformly and proportionately farther and farther from their origin $O_X$ in Figure A.11 as the output of X increases. Since the externality is neutral, the production-efficiency locus does not shift but the rays from $O_X$ along which outputs of X are measured do shift. In the case of a parametric external diseconomy, the appropriate measurement rays from $O_X$ become successively more steep as the output of X increases, e.g., from the original diagonal $O_XO_Y$ to $O_XM_1$, $O_XM_2$, and $O_XM_3$ successively. (Of course, outputs can be measured along such rays in the usual fashion because a parametric external diseconomy means that the typical firm's production function, and hence the industry aggregate production function, exhibits constant returns to scale at each given level of industry output.) Accordingly, in Figure A.11 factor

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* John S. Chipman, *External Economies of Scale and Competitive Equilibrium*, Quarterly Journal of Economics, Vol. LXXXIV, No. 3 (August 1970), pp. 347-385.

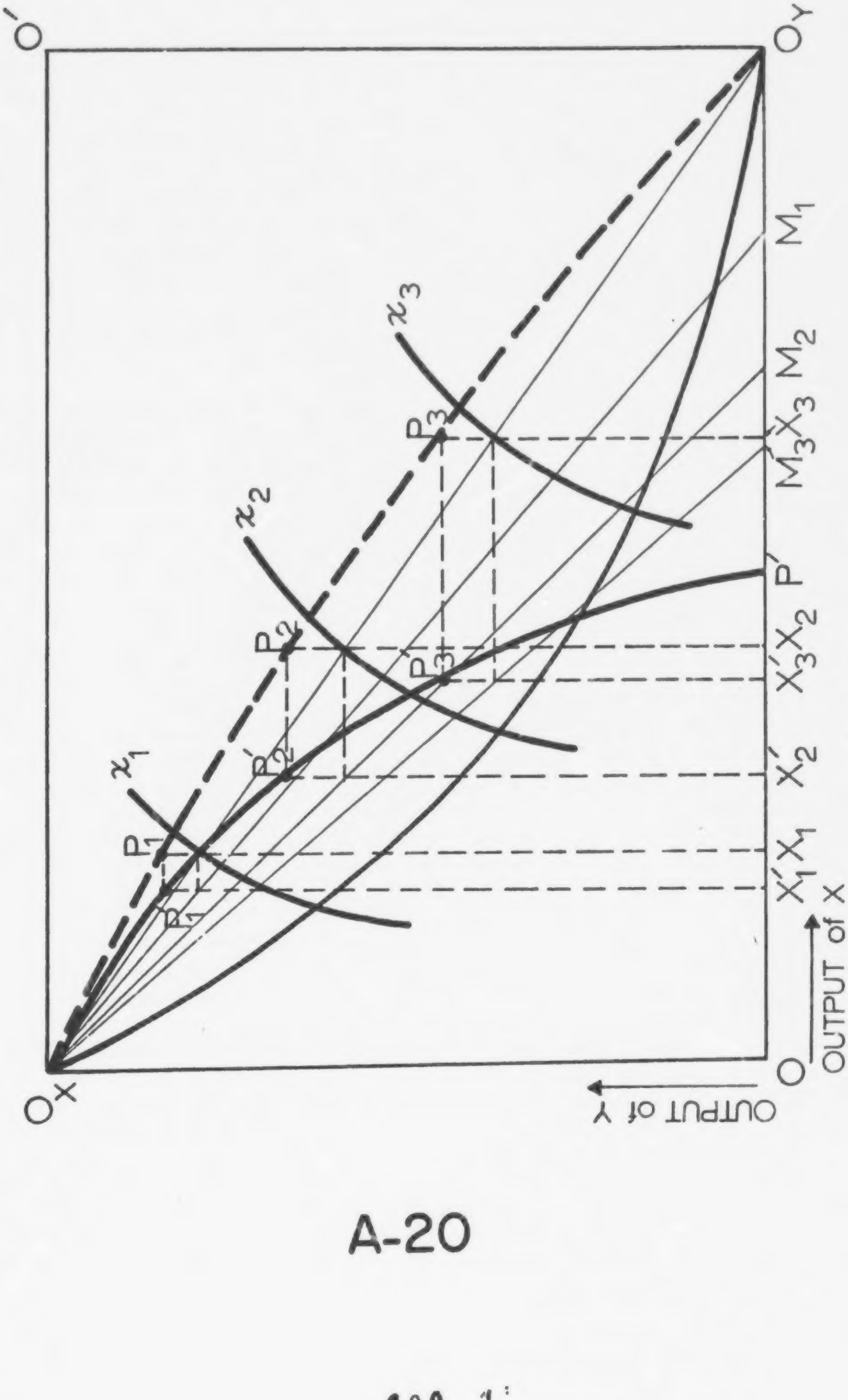
O'
O_Y
O_X
O
x_1
x_2
x_3
P_1
P_1'
P_2
P_2'
P_3
P_3'
X_1'
X_1
X_2'
X_2
X_3'
X_3
M_3
M_2
M_1
P'
OUTPUT of X
OUTPUT of Y

FIGURE A. 11

combinations which would result in outputs $OX_1$, $OX_2$, and $OX_3$ if industry output were assumed to be zero (and output could be measured as usual along the diagonal $O_XO_Y$) would provide outputs $OX'_1$ (measured along $O_XM_1$), $OX'_2$ (measured along $O_XM_2$), and $OX'_3$ (measured along $O_XM_3$) in the presence of a neutral parametric external diseconomy. Consequently, our model economy's production-possibility curve would be $O_XP'_1P'_2P'_3P'$ in the presence of a parametric external diseconomy (where $O_XP_1P_2P_3O_Y$ would be the production-possibility curve if production of X by the technology represented by isoquants $x_1$, $x_2$, and $x_3$ did not generate external diseconomies for the X industry).

Consider next a situation where the production of X generates a neutral parametric external diseconomy for industry Y that depends on the output of X. In this instance, the external diseconomy shifts Y isoquants uniformly and proportionately farther and farther from their origin $O_Y$ in Figure A.12 as the output of X increases but does not shift the production-efficiency locus. Now, however, the appropriate measurement rays from $O_Y$ become successively less steep as the output of X increases, e.g., from the original diagonal $O_YO_X$ to $O_YM_1$, $O_YM_2$, $O_YM_3$, and $O_YM_4$ successively as the output of X increases from zero to $OX_1$, $OX_2$, $OX_3$, and $OX_4$, respectively. Factor combinations which would result in outputs $OY_1$, $OY_2$, $OY_3$, and $OY_4$ if X industry output were zero (and output of Y could be measured as usual along the production box diagonal) would provide outputs $OY'_1$ (measured along $O_YM_1$), $OY'_2$ (measured along $O_YM_2$), $OY'_3$ (measured along $O_YM_3$), and $OY'_4$ (measured along $O_YM_4$) in the presence of a neutral parametric external diseconomy generated by industry X. Therefore, $O_XP'_1P'_2P'_3P'_4O_Y$ represents our model economy's production possibility curve in the presence of an external diseconomy produced by industry X, while $O_XP_1P_2P_3P_4O_Y$ would be the production-possibility curve if the production of X did not generate external diseconomies in the production of Y by the technology represented by isoquants $y_1$, $y_2$, $y_3$, and $y_4$.

Two important observations must be made before concluding this discussion of a situation where the production of X creates an external diseconomy in the production of Y.

(1) Changes in the production functions for X and Y, individually or jointly, may moderate (if not entirely eliminate) the impact of the external diseconomy associated with present production technologies. Though industry X imposes diseconomies on industry Y, the appropriate control method is not obvious. This point is treated more elaborately in the main text of this report.

(2) Where industry X generates diseconomies for industry Y, such diseconomies can (though not necessarily) result in production-possibility curves that are not entirely concave with respect to the output space origin, e.g., Figure A.12 provides an illustration of a situation where an external diseconomy generated by industry X leads to a convex production-possibility curve at relatively low outputs of Y. Therefore, phenomena typically associated with increasing returns to scale may obtain in situations where external diseconomies exist.*

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* It should also be noted that if industries X and Y were both postulated to generate parametric external diseconomies affecting one another, the production possibility curve could conceivably exhibit reversals in its usual curvature in the neighborhood of both ends.

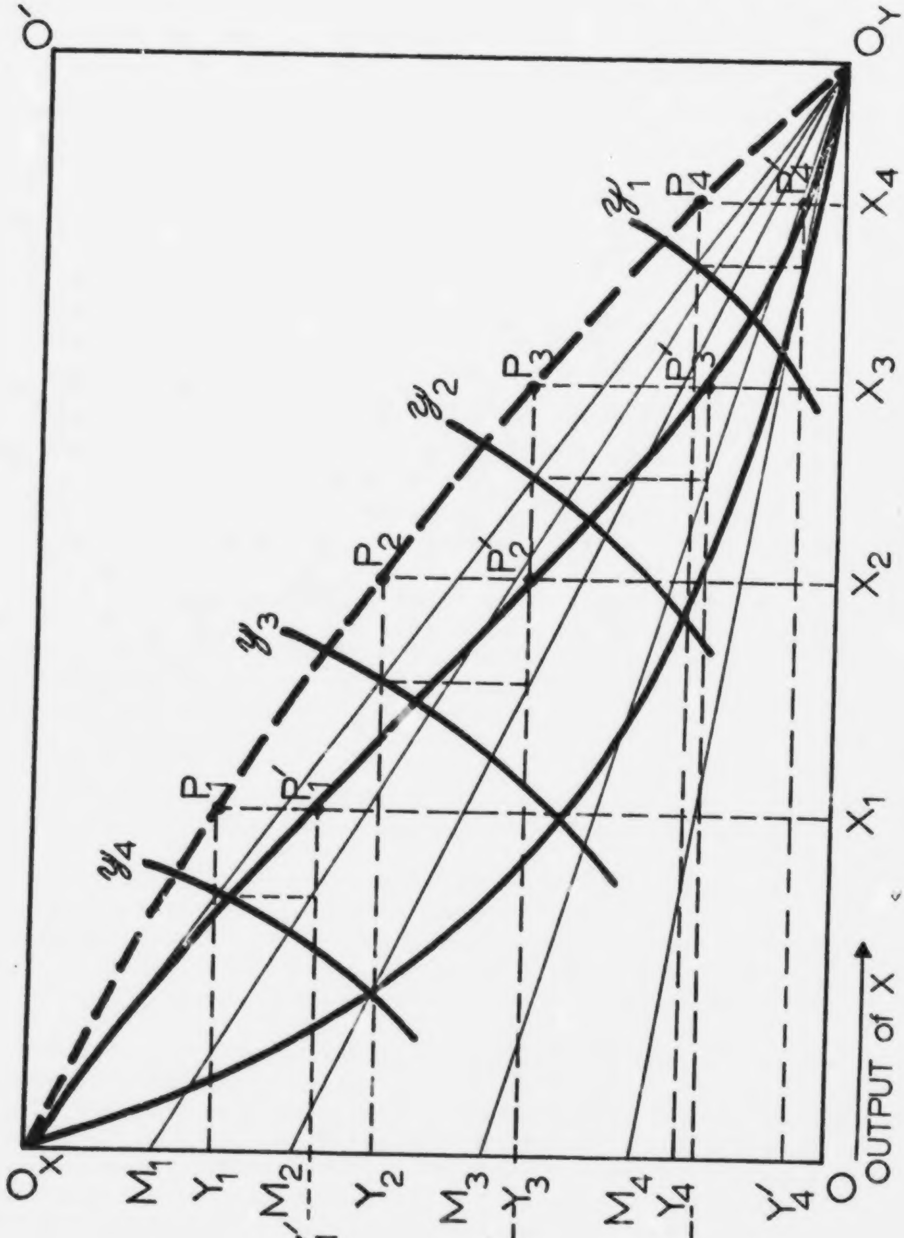
O'
O_Y
O_X
O
y_1
y_2
y_3
y_4
P_1
P_2
P_3
P_4
P'_1
P'_2
P'_3
P'_4
X_1
X_2
X_3
X_4
M_1
Y_1
M_2
Y'_1
Y_2
M_3
Y_3
Y'_2
M_4
Y_4
Y'_3
Y'_4
OUTPUT of X
OUTPUT of Y

FIGURE A.12

To this point attention has centered on output-generated parametric external diseconomies. The expositional method has relied on the device of shifting measurement rays as X industry output changed. It seems obvious that one could also adapt this same device to deal with input-generated external diseconomies: measurement rays would then be shifted as X industry employment of capital, labor, or Y (also an intermediate good in our complete model) changed. Since there would appear to be little advantage to a considerable repitition of our previous discussion, we content ourselves with the observation that the relationship between input employment (or, for that matter, output) and the magnitude of its associated diseconomies, and therefore its associated output reductions, can conceivably be quite complex. Under various "reasonable" assumptions, there would appear to be little difficulty in obtaining production-possibility curves with alternate concave and convex ranges when the magnitude of external diseconomies varies with factor employment levels and combinations.

Furthermore, to this point we have also assumed that external diseconomies have negative impacts at all levels of output and input usage. Of course, in many instances a certain "threshold" output or input use must be exceeded before an externality's effects have a discernible impact. Under such circumstances, once again only a minor adjustment in the technique developed previously is required to derive the production possibility curve. Where industry X produces an external diseconomy affecting itself, but only once some minimum output is exceeded, the measurement ray for X would be the production-box diagonal at outputs equal or less than the relevant "threshold" output, and the point on the diagonal above the threshold output would serve as the origin of the new measurement rays associated with output levels greater than the threshold output. In contrast, where industry X generates an external diseconomy for industry Y after the output of X exceeds some threshold level, there would be no change in the origin of the new measurement rays, and new rays would replace the diagonal for measurement purposes only after the output of X exceeded its threshold level. Consequently, the existence of thresholds poses no substantive problems in the derivation of production possibility curves.

Similarly, we do not here present the derivation of production-possibility curves for either capital-using or labor-using parametric external diseconomies. Such diseconomies would require us to construct diagrams much as before but for situations where both the production-efficiency locus and appropriate associated measurement rays would simultaneously shift as output and/or factor employment changed. Again, there would appear to be many "reasonable" cases, some of which would result in production-possibility curves indistinguishable from those previously derived and some of which would have alternate concave and convex ranges. Diminishing returns set in almost immediately in this sort of situation, and therefore we do not pursue the derivation of production-possibility curves under conditions of parametric external diseconomies any further here.

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# APPENDIX B

## A GENERAL EQUILIBRIUM ANALYSIS OF PRODUCTION PROCESS REGULATION

Regional general equilibrium models that explicitly allow for interindustry flows of materials often provide the most appropriate conceptual framework within which to investigate the economic consequences of alternative methods of controlling pollution. This is the case because major polluting industries are often regionally concentrated and provide a substantial fraction of the region's income by exporting some intermediate and/or final good to the "rest-of-the-world." Of course, no originality can be claimed for this observation. In fact, the Air Pollution Control Office (APCO) of the Environmental Protection Agency (EPA) recognized the need to focus on regional economies a number of years ago, and it commissioned CONSAD Research Corporation, under subcontract to TRW Systems, Inc., for the development and demonstration of a regional general equilibrium model as an operational analytical tool for evaluation of alternative pollution abatement policies. Although further refinements and new (now unavailable) data are required to make the CONSAD model system as operational as APCO presumably desires, the potential benefits of the CONSAD regional economic model system have been demonstrated--at least in part. At this time, however, despite the investigation of the effects of three air pollution control strategies in the CONSAD model, the regional and general equilibrium effects of air pollution control policies do not appear to be fully understood.

This appendix explores the positive economics of production process regulation to achieve pollution-control in simple models of closed and open regional economies with interindustry flows of materials. Viewed most broadly, the analysis is intended to acquaint the reader with the uncertainties associated with pollution abatement in the real world. Viewed slightly more narrowly, the results of the analysis for closed economies are relevant to the evaluation of national pollution-control regulations for particular industries. The results obtained for regional economies are important for the design of regulations affecting a region's export industries. In both cases, general equilibrium analysis allowing for interindustry flows of materials demonstrates that, a priori, many of the "obvious" effects of industry-wide pollution-control regulations are quite uncertain. Therefore, empirical investigations of specific regulations for particular industries in certain region(s) are required to determine the qualitative, as well as the quantitative, effects of various pollution-control policies.

The analysis is intended (a) to extend the theoretical literature on pollution-control to cover industry-wide regulations (as opposed to those affecting individual firms or small segments of an industry) and (b) to demonstrate hitherto-neglected aspects of pollution control. Throughout, the analysis assumes perfectly competitive product and factor markets and ignores the impact of regulation-induced factor price and income distribution changes on product demand.

## B.1 Analysis in Model of Closed Economy

Consider the simplest possible general equilibrium model with inter-industry flows of materials: a model with two outputs, $X_1$ and $X_2$, each of which employs labor and the output of the other industry as inputs. Formally,

$$X_1 = f_1 (X_{21}, L_1)$$

$$X_2 = f_2 (X_{12}, L_2)$$

$$L_o = L_1 + L_2$$

where $X_{ij}$ indicates the quantity of the ith commodity used by the jth industry, $L_j$ the amount of labor employed by the jth industry, and $L_o$ is some constant. As usual, $f_1$ and $f_2$ are assumed to be continuous, concave functions, which have continous first partial derivatives and are homogeneous of the first degree. These relations and assumptions are sufficient to allow derivation of the customary transformation, or production possibility, curve.

In figure B.1 outputs are measured in a positive direction and inputs are measured in a negative direction. The functions $f_1$* and $f_2$* represent $f_1$ with $L_1 = L_o$ and $f_2$ with $L_2=L_o$, respectively. They are total product curves where production at any point uses all available labor. Consequently, if a point on $f_2$* were selected, there is no production of commodity 1 except as an input in the production of commodity 2. Point B is a possible production point only with the production and trade of OG of commodity 1 as an input of commodity 2.

If A and F are the maximums of $f_2$* and $f_1$*, respectively, then all production points on ABEF, where BE is drawn tangent to $f_1$* and $f_2$*, are possible and efficient with trade allowed. However, for this model of a closed economy, the production possibility curve is CD. All efficient production points can be achieved with production activities given by the slope of OB and OE, despite the availability of many other production coefficients. Figure B.1 is therefore a geometric picture of Samuelson's Substitution Theorem.

We are now ready to employ Figures B.2, B.3, and B.4 to illustrate several important, but previously neglected, aspects of production-process regulation to obtain pollution reduction.

(1) Suppose, for example, that the Pollution Control Authority bans the production process $f_2$ and the next most efficient process is labor using, i.e., for any $X_{12}$ less $X_2$ can be produced. In Figure B.2, this shifts $f_2$* downward, results in a new lower tangency line, and shifts the production possibility curve CD downward. Regulation of production processes in industry 2 reduces the maximum possible output of both industries because industry 1 uses the output of industry 2 as an input. Moreover, in this example the new production possibility curve slopes less steeply than CD,

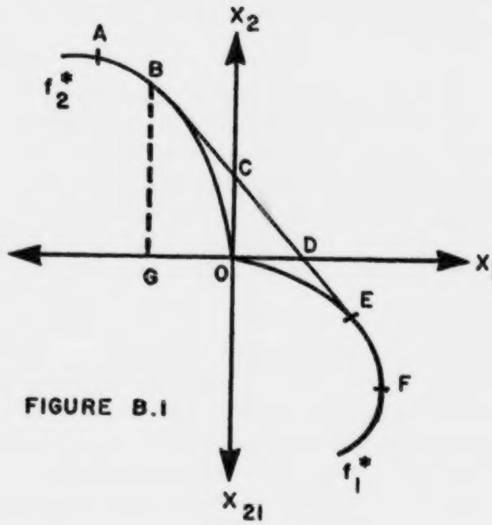

A
B
$f_2^*$
$X_2$
C
D
$X_1$
G
O
E
F
$f_1^*$
$X_{21}$

FIGURE B.1

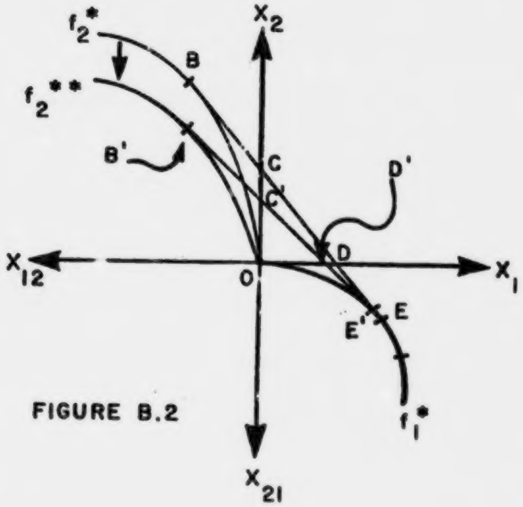

$f_2^*$
B
$X_2$
$f_2^{**}$
B'
C
C'
D'
$X_{12}$
D
$X_1$
O
E
E'
$f_1^*$
$X_{21}$

FIGURE B.2

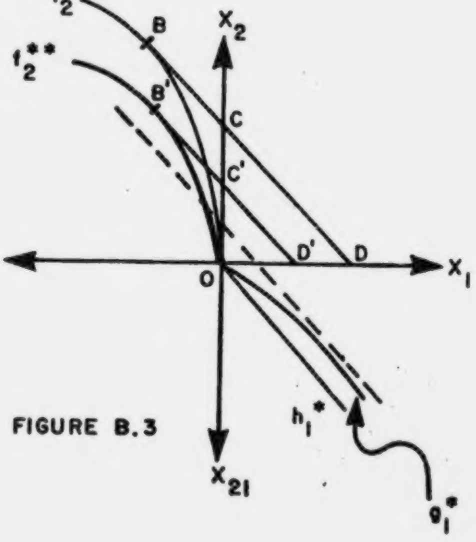

$f_2^*$
B
$X_2$
$f_2^{**}$
B'
C
C'
D'
D
$X_1$
O
$h_1^*$
$X_{21}$
$g_1^*$

FIGURE B.3

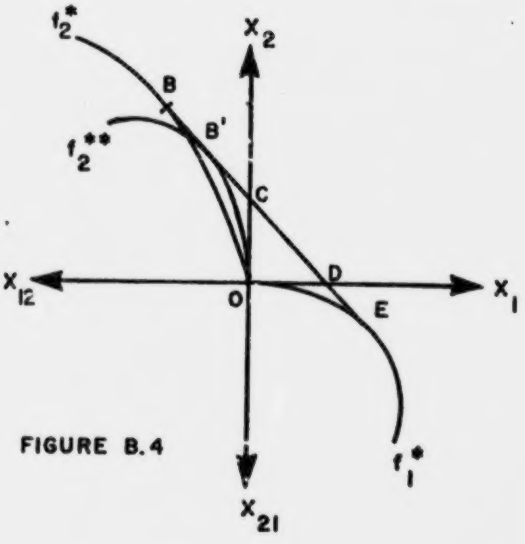

$f_2^*$
B
$X_2$
B'
$f_2^{**}$
C
D
$X_{12}$
$X_1$
O
E
$f_1^*$
$X_{21}$

FIGURE B.4

and the decrease in the maximum possible output of industry 2 is relatively greater than the decrease in industry 1. Consequently, the relative price of commodity 2 must increase.

(2) This is not the case, however, where (a) the production of commodity 1 requires no labor (see $h_1$* in Figure B.3) or (b) the asymptote to its total-product curve (see the broken line asymptotic to $g_1$* in Figure B.3) intersects the total-product curve for $X_2$ before and after the introduction of regulation. In such cases, regulation shifts the production possibility curve from CD to C'D', reduces the maximum possible output of both industries the same percentage, leaves the slope of the production possibility curve unchanged, and relative prices remain the same.

(3) Finally, consider a regulated production process change such that the same output of commodity must be produced with more labor and less commodity 1. Two possibilities exist. Either the total product curve $f_2$* shifts to a new tangency on BD at B', or it shifts downward and rightward with results identical to those already discussed. Of course, with the new production process OB' in Figure B.4, no decrease in either output is necessary, and the production possibility curve CD remains unchanged. Thus, production process regulation to achieve pollution reduction does not necessarily decrease the productive capacity of a fully-employed economy.

## B.2 Analysis in Regional Model

Consider next the simplest general equilibrium, regional model with trade in intermediate products: a model with two regions, A and B, producing two outputs, $X_1$ and $X_2$, each of which requires labor and the other commodity as inputs. Without trade or inter-regional labor migration, the productive capacity of each region is defined by

$$X_1^A = g_1(X_{21}, L_1^A)$$

$$X_1^A = g_2(X_{12}, L_2^A)$$

$$L_o^A = L_1^A + L_2^A$$

and

$$X_1^B = e_1 (X_{21}, L_1^B)$$

$$X_2^B = e_2 (X_{12}, L_2^B)$$

$$L_o^B = L_1^B + L_2^B$$

where the relations among variables and the assumptions are the same as those postulated previously.

With trade and no labor migration, each region would have a set of possible and efficient production points similar to ABEF in Figure B.1. Of course, the entire production possibility set of each region would be given by a geometric figure similar to OABEF, say, $O_A$ABEF for region A and $O_B$KLMN for region B (neither shown here). Given these conditions, there are four types of production possibility curves that are possible for the nation. These four types of national curves are obtained by "sliding" $O_A$ABEFat point $O_A$ along KLMN on $O_B$KLMN, terminating the sliding where (i) the slope of AB would become less than the slope of LM and (ii) the slope of EF would become greater than the slope of LM, and they are presented in Figure B.5. Regional differences in technologies, labor skills, and/or labor endowments generate the different shapes and sizes for $O_A$ABEF and $O_B$KLMN that result in such diverse production possibility curves for the nation.

Three observations are appropriate before investigating the effects of regulation in this model. First, and perhaps theoretically most interesting, Samuelson's Substitution Theorem does not generally apply to a nation with trade in intermediate and final products among regions despite the fact the theorem holds for each region without trade. The reason for this result is that trade permits regions to produce outputs impossible without trade. Second, the production possibility curve for the nation is not obtained by simply adding the loci of its respective regions; negative outputs of the same commodity are economically impossible for all regions. Third, ruling out corner solutions, substantial differences in regional endowments can mean that Samuelson's Substitution Theorem does hold for the nation. In such circumstances, relative prices and production coefficients are determined by a single region--the "dominant" region. Figure B.5.depicts such a situation.

Turning now to production process regulation to obtain pollution reduction, we initially ignore regulation-induced labor migration to discover how trade alters the conclusions obtained for closed economies.

(1) Suppose, as before, the Pollution Control Authority of Region A bans the production process $g_2$ and the next most efficient, permissible process is labor-using. If A is the dominant region before and after introduction of regulation, trade in intermediate and final product among regions alters none of the conclusions obtained previously; they also hold for the nation as a whole. The relative price of commodity 1 may remain unchanged or decrease, and productive capacity may decrease uniformly, differentially or not at all.

(2) Of course, if Region A were dominant and the Pollution Control Authority of Region B banned production process $e_2$, then relative prices would remain unchanged but the national production possibility curve, PP', would shift toward $O_B$ with no change in its slope.

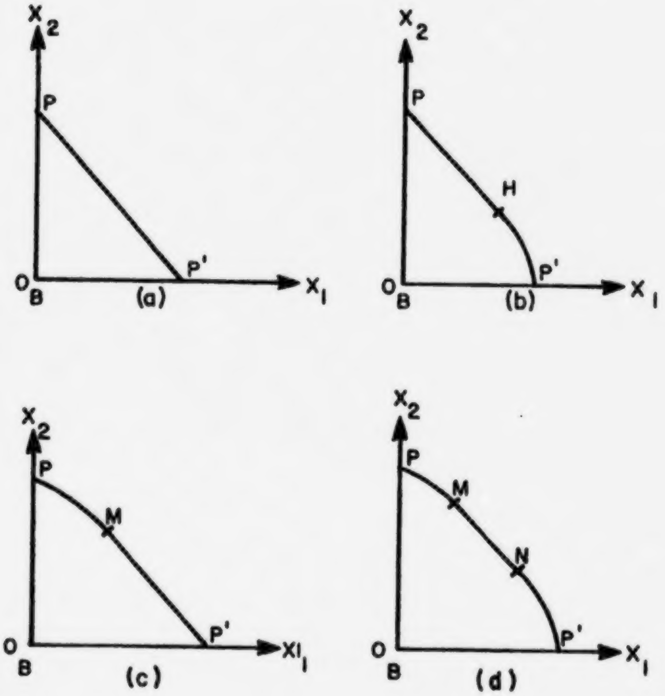

X2
P
P'
O B
(a)
X1
X2
P
H
P'
O B
(b)
X1
X2
P
M
P'
O B
(c)
X1
X2
P
M
N
P'
O B
(d)
X1

FIGURE B.5

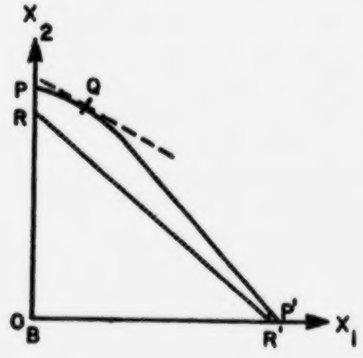

X2
P
Q
R
O B
P'
R'
X1

FIGURE B.6

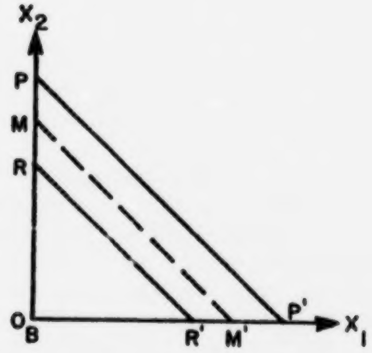

X2
P
M
R
O B
R'
M'
P'
X1

FIGURE B.7

(3) Where the Substitution Theorem does not hold for the nation, however, the effects of regional regulation are less certain because consumer demands, regional production possibilities, and regional size jointly determine the outcome. One example will suffice to demonstrate this. In Figure B.6, production possibilities are PP' before regulation, and the nation operates at point Q. Suppose that regulation shifts production possibilities from PP' to RR', i.e., the Substitution-Theorem holds for the nation after regulation is introduced. Ruling out the indeterminate corner cases on RR', the relative price of commodity 1 would increase: the slope of RR' is less than the slope of PP' at Q. Consequently, with trade and no labor migration, production process regulation in one region can result in an increase, decrease, or no change in the relative price of the regulated commodity. Of course as always, regulation would decrease the production possibilities of the "regulating" region and the nation. Without migration, total and per capita national income and income received in the regulating region decline.

In a genuine regional model, however, factors of production as well as final products are mobile. Therefore, we now relax the assumption that there is no labor migration in response to regulation-induced income differentials. Interestingly, labor mobility alters previous results only slightly. Provided the production function that replaces the one banned by the regional Pollution Control Authority is continuous, concave and homogeneous of the first degree, migration would eliminate regional per capita income differences without all labor in the regulating region migrating to the unregulated region. Diminishing returns assure this result. Consequently, labor migration following regulation would reduce the regulating region's production possibilities, expand those of other regions, and disperses the income reduction of regional pollution-regulation throughout the nation.

Figure B.7 neatly depicts the impact of different assumptions concerning labor mobility. As before, regulation in one region would shift national production possibilities from PP' to RR' with no inter-regional movement of labor. However, if labor is mobile and responds to wage differences, national production possibilities would shift from PP' to MM' rather than RR'. Otherwise, none of the earlier predictions are altered. Factor mobility merely moderates the income-reducing effects of pollution controls; it does not alter the a priori indeterminacy of the impact of pollution controls on relative commodity prices.

## APPENDIX C

## PRIVATE PRODUCTION POSSIBILITIES AND EFFICIENT GOVERNMENT PRODUCTION OF PUBLIC GOODS

This appendix examines some of the implications of the suboptimization technique frequently recommended by management consultants, cost-effective specialists, and benefit-cost analysts in their reports to public agencies. One of their most common recommendations involves the application of traditional economic efficiency criteria to the design and operation of government facilities to produce public-good service outputs in amounts which may or may not approximate an unknown optimum. To be precise, they suggest that the marginal rate of technical substitution between factors in public production be the same as that obtaining in private production. (Of course, this suggestion is most often expressed in less technical language.) The implications of this efficiency rule are typically either regarded as obbious or the reader is referred to a standard microeconomic theory textbook where efficiency in private good production is demonstrated to require satisfaction of this rule. However, where the amount of a good to be produced is determined by, say, legislative or executive action instead of consumer demand and, therefore, may or may not approximate some unknown optimum, an additional constraint has been introduced, and the general theory of the second best would suggest that application of the recommended efficiency rule may have unsuspected and unintended results. For this reason, this appendix reports a general equilibrium analysis of the impact on private production-possibilities of the recommended efficiency rule for government production of a public good. The analysis shows that "efficient" production of some given finite public good output implies a petal-shaped transformation curve for private outputs rather than the usual convex, continuously negatively-sloped transformation curve typically postulated in the literature. The appendix concludes by discussing some implications of this finding.

### C.1. Mathematical Analysis

Assume three Cobb-Douglas production functions

$$X = L_X R_X^{1-\alpha} \tag{1}$$

$$Y = L_Y R_Y^{1-\beta} \tag{2}$$

$$G = L_G R_G^{1-\gamma} \tag{3}$$

where $L_i$ equals labor employed and $R_i$ is the capital-labor ratio in the relevant sector. Factor supplies are assumed to be fixed

$$L_X R_X + L_Y R_Y + L_G R_G = K \quad (4)$$

$$L_X + L_Y + L_G = \bar{L} \quad (5)$$

where $\bar{K}$ and $\bar{L}$ are the fixed endowments of capital and labor. These equations can be rewritten as

$$gR_G + (1-g)R_p = R \quad (6)$$

$$hR_X + (1-h)R_Y = R_p \quad (7)$$

where g is the proportion of the total labor endowment employed by the government and h is the proportion of privately employed labor allocated to the production of X.

Following Hary G. Johnson (Econometrica, July 1966), with no government $L_G$, $R_G$, and g equal zero, while $R_p$ equals R. Assuming competitive conditions in private markets, long-run equilibrium implies that the marginal rates of technical substitution between factors are the same in industry X and Y, i.e.,

$$\frac{\alpha}{1-\alpha} R_X = \frac{\beta}{1-\beta} R_Y \quad (8)$$

and, therefore, using (7)

$$R_X = \frac{bR}{a + (b-a)h} \quad (9)$$

$$R_Y = \frac{aR}{a + (b-a)h} \quad (10)$$

where $a = \frac{\alpha}{1-\alpha}$ and $b = \frac{\beta}{1-\beta}$. Taking advantage of (9) and (10), (1) and (2) can be rewritten as

$$X = (h)(L) \left[ \frac{bR}{a + (b-a)h} \right]^{1-\alpha} \quad (11)$$

$$Y = (1-h)(L) \left[ \frac{aR}{a + (b-a)h} \right]^{1-\beta} \quad (12)$$

Differentially (11) and (12) with respect to h, Johnson obtained

$$\frac{dX}{dY} = \frac{\frac{dX}{dh}}{\frac{dY}{dh}} = -(bR)^{1-\alpha} (aR)^{\beta-1} (a + (b-a)h)^{\alpha-\beta} \frac{a + h(b-a)}{a + (b-a)(1-\beta-\beta h)} \quad (13)$$

Thus, the normal transformation curve is negatively sloped.

Efficient government production of public goods would appear to most economists to require that the marginal rate of technical substitution between factors in public production be the same as that obtaining in private production, or

$$a\ R_X = b\ R_Y = c\ R_G \tag{14}$$

where $c = \frac{\gamma}{1-\gamma}$. Postulating efficient government production of some finite public good output $\overline{G}$ in precisely the sense of (14), we now seek to determine whether the transformation curve for private outputs X and Y is continuously negatively sloped.

Given that (14) means

$$R_X = \frac{c}{a} R_G \text{ and } R_Y = \frac{c}{b} R_G,$$

production functions (11) and (12) can be rewritten as

$$X = h\ (\overline{L} - \overline{G}R_G^{\gamma\ 1})\ (\frac{c}{a} R_G)^{1-\alpha} \tag{15}$$

$$Y = (1-h)\ (\overline{L} - \overline{G}R_G^{\gamma -1})\ (\frac{c}{b} k_G)^{1-\beta} \tag{16}$$

where privately available and employed labor is $\overline{L} - \overline{G}R_G^{\gamma-1}$. Differentiating (15) and (16) with respect to $R_G$ and performing some minor algebraic manipulation, we obtain

$$\frac{dX}{dY} = \frac{\frac{dX}{dR_G}}{\frac{dY}{dR_G}} = (\frac{h}{1-h})\ (\frac{c}{a})^{1-\alpha}\ (\frac{c}{b})^{\beta-1}\ R_G^{\beta-\alpha} \left[ \frac{(1-\alpha)\overline{L}-(\gamma-\alpha)\overline{G}R_G^{\gamma -1}}{(1-\beta)\overline{L}-(\gamma-\beta)\overline{G}R_G^{\gamma -1}} \right] \tag{17}$$

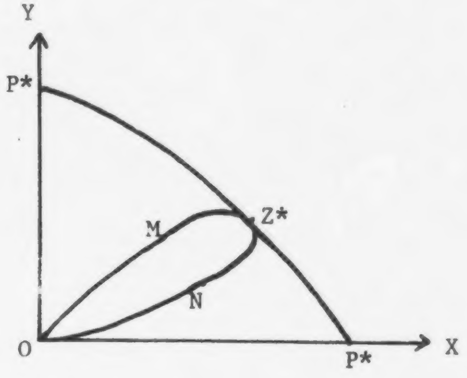
Since the sign of the bracketed term in (17) varies with $R_G$ if $\alpha \neq \beta$, the slope of transformation curve between X and Y given efficient production of $\overline{G}$ as defined by (14) also varies with $R_G$. Consequently, the transformation curve for private outputs under the assumed conditions is petal-shaped rather than continuously negatively-sloped.

## C.2. Discussion and Implications

The reason for the foregoing, previously unsuspected result is that efficient production of a given public good output introduces three additional constraints into the standard two-good-two-factor general equilibrium model. These additional constraints are (1) the given level of public good output, (2) the production function for the public good, and (3) the "efficiency rule" requiring that the marginal rate of technical substitution between factors in public good production equal the marginal rate of substitution in private production. Of course, once the additional constraints are explicitly stated and recognized, the general theory of the second best would immediately suggest to most economists that relationships which held prior to the introduction of the constraints may be subject to serious qualification. Thus, in an important sense, our result cannot be regarded as particularly surprising.

On the other hand, this finding does have important implications for public policy. Some of these implications may be illustrated most clearly with the aid of Figure C.1, which presents two transformation curves. OMZ*NO represents the petal-shaped private good transformation curve that would obtain if the government followed the usually recommended efficiency rule in producing some given amount of public good output, $\overline{G}$, while P*Z*P* represents the maximum attainable combinations of private good outputs X and Y such that public good output equals $\overline{G}$. (The marginal rate of technical substitution between factors in public production would equal that in private production at all points on OMZ*NO but only at point Z* on P*Z*P*.)

Figure C.1.



Following the often-recommended efficiency rule would minimize the private output reductions associated with public good production if and only if demands for private goods would result in the production of the Z* output combination. If private demands would lead to the production of any output combination other than Z* on OMZ*NO, then the government would only appear to minimize the cost of public good output by equating its marginal rate of technical substitution between factors with that rate of substitution obtaining in the private sector. In fact, by following the usual efficiency rule the government would impose a substantial unnecessary constraint on the private sector: the output space enclosed by OMZ*NO is considerably less than that enclosed by OP*Z*P*O.

Our major conclusion is obvious. Genuine suboptimization where some given output of pure public goods is produced will typically require deliberate violation of economists' usual cost minimization rule. Determination of the appropriate factor combination for truly efficient production of non-market-determined public good outputs is considerably more complex than has previously been recognized.

# APPENDIX D

# THE POLLUTION PRODUCTION FUNCTION

## D.1. The Importance of the Pollution Production Function

An important fraction of our continuing research effort has been devoted to the specification and estimation of the pollution production functions associated with open burning of agricultural fields in the Willamette Valley. Open field burning produces smoke that, depending upon atmospheric conditions, is transported to various points in the Valley or out of the Valley. To economists, the problem of accounting for the impact of this burning process on visibility appeared analogous to the problem in economics of estimating what is called a 'production function'. A production function is an analytical concept that asserts the existence of a set of fixed relationships between an output or set of outputs on the one hand and a set of inputs on the other. For economists, the problem of estimating production functions has been confined to providing adequate specification of the reasonable independent variables in the process and ascertaining, *a priori*, what mathematical form this production process might reasonably take. Economists have had some success in the empirical estimation of particular production functions.*

In our research, a pollution production function has been regarded as an analytical concept that postulates the existence of a set of stable relationships between daylight visibility in particular locations in the Valley under varying present and recently past meteorological conditions and recently past emission rates throughout the Valley. Meteorological conditions determine how the atmosphere transports emissions from field burning from one location to another in the Valley, and acres burned determine emission rates and atmospheric loading in different zones of the Valley. Meteorologists have described the Willamette Valley as a box with a movable lid and a set of ventilating windows.** Alternative specifications of relevant meteorological variables consistent with that model have been explored in our research. Empirical estimation has concentrated on functions with minimum daylight visibility at Eugene and Salem as the dependent variable and acres-burned among the independent variables.

There are two reasons why our research initially and continuously has focused quite intensively on estimation of the pollution production function. First, research success promised to provide immediately valuable information for the Oregon Department of Environmental Quality in the development of its field burning control policy to minimize the harmful effects associated with smoke produced by open burning of agricultural fields. For precisely this reason, Bruce Snyder, the meteorologist with the DEQ, and faculty members of the Department of Atmospheric Sciences at Oregon State University have generously supplied data and advice throughout our research. Second, and most important given our research objectives, measurement of the benefits to be obtained from various field burning control policies is impossible without the pollution production function. This is the case because the pollution production function is a major determinant of the marginal valuation schedule of air quality improvements from field burning control.

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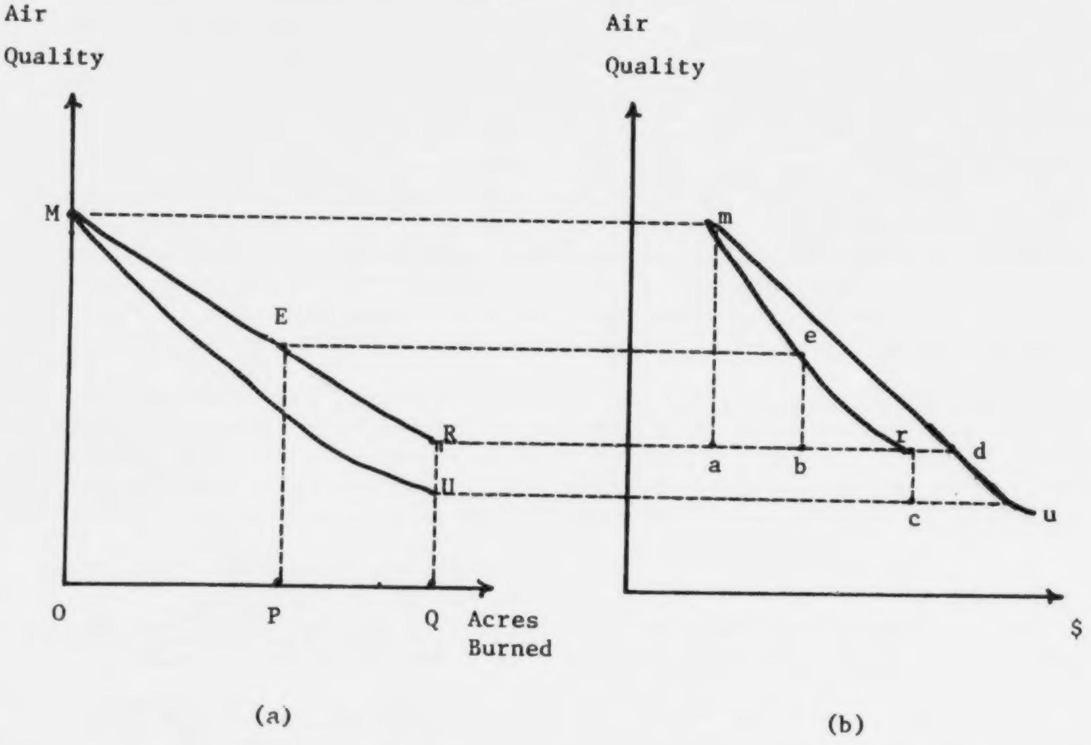
* For example, see Marc Nerlove, *Estimation and Identification of Cobb-Douglas Production Functions*, Chicago: Rand McNally, 1965.

** Olsson, Lars E. and Wesley L. Tuft, *A Study of the Natural Ventilation of the Columbia-Willamette Valleys*, Technical Report No. 70-6, Department of Atmospheric Sciences, Oregon State University, Corvallis, Oregon, June 1970, pp. 133-137.

Assuming known pollution production functions and a known (constant or declining) marginal value schedule for successive improvements in air quality, the above point may be established with the aid of Figure D.1, where an (unspecified) index of air quality is measured along the vertical axis, while acres-burned and the marginal value of successive air quality improvements are measured horizontally in panels (a) and (b), respectively. In panel (a), curves MR and MU illustrate hypothetical relationships derived from pollution production functions estimated under conditions where burning is and is not regulated according to prevailing and forecast air quality and meteorological conditions. In panel (b), the marginal valuations of successive improvements in air quality are plotted with and without well-regulated burning, and mr and mu are associated with MR and MU, respectively.

Figure D.1.



Following standard benefit measurement techniques, the gross benefits of field burning regulated according to prevailing and forecast air quality and meteorological conditions would be measured by the area rcud with no reduction in total acres burned. Furthermore, since the benefits rcud are obtainable with no reduction in total acres burned, the maximum benefits from a complete ban of field burning would be measured by the area mar, whereas regulated burning coupled with an acres-burned reduction equal to PQ would result in benefits measured by ber. Consequently, correct estimation of the benefits derived from all field burning control programs would be quite impossible without the pollution production function.

## D.2. The Model

The basic hypothesis of our model is that daylight visibility is a function of prevailing meteorological conditions and the load of contaminants placed in the atmosphere by pollutors. However, since atmospheric load at any given location and time is itself a function of present and recently past contaminant emission rates at that and other locations, a more complete and accurate statement of the hypothesis would be as follows. Daylight visibility at a given location is a function of (1) the present and recently past air-contaminant emission rates at that and other locations and (2) the present and recently past capacity of the atmosphere to dilute and transport its contaminants from one location to another.

Operational specification of this hypothesis is no simple task. Contaminants are emitted at non-uniform rates from numerous sources for which data are limited or not available while atmospheric dispersion and transportation processes are complex and meteorological data above the surface are obtained only twice per day for the Willamette Valley. Consequently, for statistical testing, daily variations in minimum daily visibility are hypothesized to be "explained" by variations in different sets of independent variables reflecting air-contaminant emission rates and the atmospheric transportation process. Alternative specifications of the present and past emission rates (via various proxy variables) and the capacity of the atmosphere to disperse and transport contaminants require discussion, however, prior to the presentation of our results.

Although atmospheric load is the result of emissions from numerous sources, the primary concern here is with the atmospheric loading effect of field burning on visibility. Therefore, the research is designed to test a strong hypothesis about the visibility-field burning relationship. This is accomplished by employing (a) a theoretically reasonable data configuration, (b) an explicit hypothesis concerning emissions from other than field burning sources for which data are not now systematically collected, and (c) proxy variables for daily field burning emission rates and background load before fields are burned on any given day. This procedure means that field burning is treated as an important marginal contributor to atmospheric loading. Variations in field burning emission rates together with variations in the background load and emissions from sources other than field burning are regarded as jointly determining variations in atmospheric loading.

Regarding the selected data configuration, data are excluded for days on which field burning was less than 100 acres in total. Although the decision to confine consideration to 100-plus acre burning days is admittedly arbitrary, it does not appear unreasonable.

Unfortunately, despite the importance of automobiles, pulp mills, etc. as sources of air contaminants, no daily data are systematically collected on emissions from these sources. Without these data, it is hypothesized that daily emissions from these sources are regular and stable and that, therefore, they can be treated analytically as constant.

Regarding field-burning emission rates, the number of acres burned throughout, or in particular zones of, the Willamette Valley serve as a proxy for field-burning emissions. Data are available on the acreage of total field burning permits issued daily by fire district in 1969 and 1970, and these data can be aggregated to reflect the burning in various zones of the Valley or in the Valley as a whole. In contrast, however, there is no need to identify or measure the sources of the varying daily initial background load existing prior to each day's field burning. This is because background load is appropriately treated as a predetermined variable (i.e., determined by emissions from many sources on the previous day(s) as well as past meteorological conditions). Here, visibility at 7 a.m. at the location under study provides the proxy for background load.

Turning next to the capacity of the atmosphere to dilute and transport its load, the variables that seemed most appropriate were mid-afternoon inversion height, atmospheric stability, wind speed, and wind direction. Although we had access to the full range of meteorological data, we deliberately did not seek to use it all. In our view, whatever model we hypothesized and tested, it was essential to minimize colinearity among the independent vaiables. For this reason other variables generally associated with atmospheric stability (such as surface temperature, relative humidity counts, etc.) were excluded.

Regarding the empirical data, several problems deserve note. The data on inversion height were measured in millibars of pressure and used in this form. Hence, the relationship between inversion height and minimum daylight visibility was predicted to be negative: the higher the measured inversion pressure, other things equal, the lower would be visibility. We recognize one shortcoming of the analysis in that no donsideration was given to the thickness of the inversion layer.

Utilization of a stability measure that was theoretically plausible and empirically meaningful was difficult. Daily data are available on air temperature changes between the surface and 900 millibars, 800 and 900 millibars, and 700 and 800 millibars. These air temperature change data are measures of stability. For purposes of model specification, the problem was to select a particular band, a combination, or use all three bands as stability proxies. The appropriate measure or measures of stability should reasonably be confined to the mixing layer. After considering the direction of the prevailing winds and the height of the Cascade Range, it was decided to use the air temperature change data in the surface to 900 millibar range as the measure of stability.

The character of the physical problem being considered suggested that wind direction must play a prominent role in the analysis. The problem was how to treat it. The method of measuring wind direction makes the data difficult to use if one attempts to employ continuous variables. Two schemes were considered which relied on arbitrary designation of winds from the north, south, east, and west. One of these schemes employed a weighting arrangement for simultaneously taking account of both wind speed and direction. Given the measurement and data problems and given the predicted strong relationship between wind direction and low visibility in Eugene and Salem, it was decided to take wind direction into account by a data sorting technique. That is, winds from the north could potentially contribute to deterioration of the visibility at Eugene and Salem. On the other hand, given the locations of Eugene and Salem, winds from the south should improve visibility. Therefore, it was decided to investigate (a) visibility in Eugene only on days with winds from the north and (b) visibility at Salem first, on days with north winds and, second, on days with southerly winds.

Reference has been made to the "relevant wind". Wind measurements are available at both the surface and at 850 millibars. Meaningful analysis required that a decision be made as to which measure to use. The relevant data are clearly those that apply to the mixing layer. If the inversion height was lower than 850 millibars (i.e., more than 850 millibars of pressure) the only relevant wind data on speed and direction was provided by the surface measurements. On the other hand, if the inversion pressure was above 850 millibars it seemed reasonable that measurements of wind direction and speed at 850 millibars would be utilized in the analysis. We adopted this as a selection rule for determining which measurements of wind speed and direction were considered for each day. Furthermore, in the model variants where wind speed was treated as an independent variable, the data were expressed in knots per hour.

Specification of the empirical data which could reasonably serve as proxies for the theoretical determinants of minimum daylight visibility was but one portion of the model specification problem. Completion of this problem required specification of a theoretically plausible mathematical form. Adopting the principle of "Occam's Razor" as a guide, first, we tested a linear version of the model. Next we examined a form in which the independent variables were treated as multiplicative and the function as exponential. This form was plausible on physical grounds as well as having achieved noteworthy success when adopted for estimating economic production functions. For statistical purposes, the multiplicative-exponential form meant estimation of equations linear in the logarithms of all variables.

## D.3. Statistical Results*

Five variants of our basic model have been tested for Eugene and Salem on 1969, 1970, and 1971 data for days on which at least 100 acres burned. These variants differ from one another according to their respective specifications of the independent variables reflecting atmospheric capacity to dilute and transport load. The model variants, expressed in general form, are as follows:

I. $V = V_I\ (A,\ V_{7A})$

II. $V = V_{II}\ (A,\ V_{7A},\ I_{4P})$

III. $V = V_{III}\ (A,\ V_{7A},\ I_{4P},\ W_S)$

IV. $V = V_{IV}\ (A,\ V_{7A},\ I_{4P},\ S)$

V. $V = V_V\ (A,\ V_{7A},\ I_{4P},\ W_S,\ S)$

where V = minimum afternoon daylight visibility at the Eugene or Salem airport, A = total acres burned in the Willamette Valley or total acres burned north and/or south of the Salem airport according to the relevant wind direction at 4 p.m., $V_{7A}$ = visibility at 7 a.m. at the Eugene or Salem airport, $I_{4P}$ = inversion height at 4 p.m., $W_S$ = relevant wind speed at 4 p.m., and S = atmospheric stability at 4 p.m.

As mentioned above, the mathematical forms assumed for purposes of analysis were the linear and lot - log forms. Interestingly, the estimated relationships and the statistical significance of the regression coefficients did not vary dramatically between functional forms. However, for all models the fits in terms of both $R^2$ and the F-statistic were clearly better when the log - log form was employed. Consequently, this appendix reports regression results for models in log - log form only.

The multiple regression results obtained for each model variant, as well as the beta coefficients of each regression coefficient, are reported in Tables D.1 through D. 15. (Since the size of estimated regression coefficients varies with the units in which each independent variable is stated, regression coefficients do not indicate the importance of the independent variables in statistically explaining variations in minimum afternoon daylight visibility in Eugene or Salem. Such information can be deduced from beta coefficients, however. Beta coefficients convert regression coefficients into standardized units. Here, the beta coefficients measure the effect on minimum daylight visibility of typical changes in the independent variables in terms of sample standard deviations.) Tables D.1 through D.10 present regression results for Eugene and Salem with winds from the north in 1969-70, 1971 and 1969-70-71, while Tables D.11 through D.15 report our regression findings for Salem under southerly wind conditions during 1969-70, 1970-71, and 1969-70-71.

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* The results reported in this section extend and superside those presented in our second annual report (dated June 1971) and our paper "Field Burning and Visibility Reduction in the Willamette Valley: A Pollution Production Function", which was given at the Eighth Annual Meeting, Pacific Northwest International Section, Air Pollution Control Association, Spckane, Washington, November 18, 1970.

Viewed most broadly, the regression results reported in Tables D.1 through D.15 are noteworthy on three counts. First, the results for 1969-70 and 1969-70-71 support the predictions of our simple atmospheric models reasonably well. Second, the rather poor performance of the same models in 1971 directly derives from the burning regulations applied by the Oregon Department of Environmental Quality, Air Quality Control Division. Third, despite significant changes in burning regulations over the 1969-70-71 period, the regression coefficients obtained for the acres burned variables are remarkable stable in size. Since acres burned are subject to direct control, this finding has considerable importance for the design of smoke management and field burning control policies. The evidence to support these judgments follows.

Consider first our results for Eugene and Salem under northerly wind conditions in 1969-70 and 1969-70-71. For these periods, all statistically significant and insignificant variables have their theoretically anticipated signs and therefore support the simple atmospheric models postulated here. Minimum daylight visibility varies inversely with relevant (i.e., north and/or south) acres burned and atmospheric stability and directly with visibility before burning, mid-afternoon inversion height (recall that inversion heights are measured here in millibars of pressure), and relevant wind speed. Moreover, only the statistically insignificant regression coefficient for atmospheric stability changes substantially in size and relative importance when one examines alternative specifications of the atmospheric load transportation and dilution mechanism for the same time period or between the two time periods. Otherwise, alternative specifications of our models hardly change the regression coefficients for relevant acres burned, visibility before burning, inversion height, or wind speed. This stability in the size of regression coefficients is particularly important because the specification of the log - log functional form means that the estimated coefficient provides a direct measure of the elasticity of minimum visibility with respect to the various independent variables.* For example, the estimated regression coefficient for South-Valley-acres-burned in Table D.2 indicates that a 10 percent change (above or below the 1969-70-71 average) would have meant an opposite 3-3.5 percent change in Eugene minimum visibility in 1969-70-71 period, holding all other variables constant.

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* The elasticity of a dependent variable with respect to some independent variable indicates the responsiveness of the former to changes in the latter and is measured by the percentage change in the dependent variable divided by the percentage change in the independent variable, all other independent variables being held constant.

Furthermore, with few exceptions, it is encouraging to note that the most important independent variables in terms of their respective beta coefficients are the statistically significant acres burned, visibility before burning, and inversion height variables. Since statistically significant regression coefficients are not always associated with relatively large beta coefficients, this evidence suggests that model variants II and III are superior to variants I, IV, and V in terms of statistical explanatory power as well as in terms of goodness of fit as indicated by their respective $R^2$ and F-statistics. Consequently, our regression results provide support for the hypothesis that daylight visibility in the Willamette Valley is a function of the load of contaminants placed in the atmosphere by pollutors and the prevailing meteorological conditions. This conclusion holds with equal force for Eugene and Salem.

For Eugene, when winds were from the north, a statistically significant relationship obtained (see Table D. 1, 2, 3, 4, and 5) between variations in minimum daylight visibility and relevant acres burned, as well as other independent variables reflecting air-contaminant emission rates and the atmospheric transportation process. These findings clearly establish the impact of field burning smoke on visibility at Eugene. Furthermore, these findings support the fundamental correctness of the 1970 and 1971 Department of Environmental Quality field burning program and schedule to reduce deterioration of visibility in Eugene by curtailing acres burned under north winds. Also, Tables D.1 through D.5 corroborate the DEQ finding that smoke from North Valley burning was an important determinant of visibility in Eugene in 1969 and 1970.*

In the case of Salem under northerly wind conditions, however, considerably less robust results were obtained for each of our five models. A comparison of Tables D.6-D.10 with Tables D.1-D.5 indicates that the goodness-of-fit as measured by $\bar{R}^2$ and F-statistics is less in all time periods for every model for Salem than for Eugene. Although all Salem regression coefficients have their theoretically anticipated signs in the 1969-70 and 1969-70-71 periods, a comparison of beta coefficients indicates that the relative importance of visibility at 7 a.m. (an index of background load before burning) is greater for Salem than Eugene, while mid-afternoon inversion height is less important at Salem. Nonetheless, the statistical significance and importance of acres-burned in the northern half of the Valley is clear; variations in acres-burned contribute to variations in minimum visibility.

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* Department of Environmental Quality, Air Quality Control Division, "Field Burning in the Willamette Valley, 1970," staff report dated April 8, 1971, p. 14.

Finally, for Salem under southerly wind conditions (see Tables D.11, 12, 13, 14, and 15), a statistically important relationship obtained over the 1969-70-71 period between minimum daylight visibility and acres burned in the South Willamette Valley, visibility before burning in Salem, and the mid-afternoon inversion height at Salem. Other indexes of atmospheric load before burning (e.g., minimum visibility at Eugene) produced weaker statistical results than those reported here. The theoretically unanticipated signs for the wind speed and atmospheric stability variables are fortunately associated with statistically insignificant and relatively unimportant (in terms of the size of their beta coefficients) variables.

Of course, these findings for Salem and Eugene demonstrate the conflict inherent in the 1970 and 1971 DEQ field burning program to minimize visibility losses in Eugene by reducing South Valley acres burned under north winds while allowing large South Valley acreages to be burned with south winds. Burning South Valley acreage under northerly wind conditions reduces visibility in Eugene, while burning such acreage with south winds lowers visibility in Salem. Such conflicts are necessarily involved in smoke management programs which attempt to minimize the harmful effects of field-burning smoke by attempting to control the distribution rather than the volume of the smoke. These conflicts are discussed extensively in the main text of this report.

We next turn to the exceptionally poor performance of our five models when fit to 1971 data for Eugene and Salem. Tables D.1 through D.10 indicate that every model had an $\bar{R}^2$ equal to zero and numerous statistically insignificant regression coefficients with theoretically unanticipated signs when fit to 1971 data. In the case of Eugene (see Tables D.1-D.5), the only variable with a regression coefficient statistically significant at the 20 or 30 percent level is acres burned in the southern half of the Willamette Valley. For Salem (see Tables D.6-D.10), the only coefficients statistically significant at the 20 or 30 percent level are those for acres burned in the northern portion of the Willamette Valley. Most of the other variables were statistically insignificant and had signs contrary to our theoretical expectations.

Needless to say, these poor results for 1971 suggested that further analysis was required. Two types of additional analysis were undertaken. First, an analysis of variance was performed to test whether the set of coefficients in our estimated models for 1971 was significantly different from the set of coefficients for the same models fit to 1969-70 data, i.e., do the models fitted separately to 1969-70 and 1971 periods statistically explain significantly more variation in minimum daylight visibility than the same models for the 1969-70-71 period as a whole.* Second, a detailed analysis of the 1969-70 and 1971 data was performed to determine whether the observed changes in our regression results are related, at least in part, to the apparent increasing effectiveness of the DEQ regulated burning policy over the 1969-70-71 period. The results of these analyses follow.

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* See Gregory C. Chow, "Tests of Equality between Sets of Coefficients in Two Linear Regressions," Econometrica, Vol. 28, No. 3 (July 1960), pp. 591-605 for the appropriate testing procedure and definition of the test statistic.

Despite the very substantial decrease in the goodness-of-fit of our models between the 1969-70 and 1971 subperiods, an analysis of variance indicated that we could not reject at the 10 percent level the hypothesis that for Eugene the two sets of regression coefficients for all five models came from the same population. The apparent explanation for this finding lies in the rather great similarity in the size of most regression coefficients for the two subperiods, especially the similarity in the size of the most important (in terms of its beta coefficient) South-Willamette-Valley-acres-burned variable.

In the case of Salem, however, an analysis of variance indicated that we could reject at the 5 percent level the hypothesis that the 1969-70 and 1971 sets of regression coefficients come from the same population for model II and at the 10 percent level for models III, IV, and V. These findings suggest only a rather limited shift in the underlying atmospheric mechanism to dilute and transport load between the 1969-70 and 1971 periods.* Since meteorological conditions were basically the same over the 1969-71 period, these findings in turn suggested the possibility that the effectiveness of DEQ burning regulations changed over the period, thereby contributing to the poor performance of the models when fit to 1971 data.

Field burning regulations, schedules, and actual acres burned under different meteorological conditions were redesigned each year over the 1969-71 period in an attempt to keep smoke away from the Eugene-Springfield area while having a minimal effect on Salem. With controls of varying stringency, the DEQ simultaneously redistributed and reduced daily acreage burned under northerly wind conditions and increased acreages burned under persistent southwesterly winds. Since the daily decision concerning which acreages to be burned was made early each morning on the basis of the then existing air quality conditions plus predicted meteorological conditions for later in the day, significant and (perhaps) systematic differences in our regression results would be expected following implementation of a positive burning policy. Consequently, with controlled variations in acres burned according to visibility-before-burning and predicted afternoon meteorological conditions, one would expect to observe a deterioration in the performance of our models over the 1969-71 period.

A careful study of Table D.16 reveals how DEQ burning regulation policies and improved prediction of afternoon meteorological conditions have jointly caused our models to perform uniformly poorly in 1971 when compared with earlier years. Table D.16 reports the simple correlation coefficients between acres burned in the northern and southern sections of the Willamette Valley, visibility-before-burning, and mid-afternoon inversion height in 1969, 1970, 1969-70, and 1971 at Eugene and Salem. Since positive field burning control policies aimed at keeping smoke away from Eugene and Salem would imply positive correlations between acres burned, visibility at 7 a.m., and mid-afternoon inversion height (recall that inversion height is measured here in millibars of pressure), it is encouraging to note that 5 of 6 correlation coefficients for 1971 have signs consistent with such positive control policy whereas only 2 of 12 signs in 1969 and 1970 are consistent with a positive policy. Unquestionably the most dramatic policy reversal occurred with respect to acres burned in the South Willamette Valley under northerly wind conditions. In 1969-70 the simple correlation coefficient between South acres-burned and visibility before burning equalled -0.394 while in 1971 it equalled 0.404, and a perverse policy in 1969-70 became a positive policy in 1971. Consequently, in the case of both Eugene and Salem, an effectively implemented DEQ burning control policy appears to contribute to explaining the rather poor performance of our simple models when fit to 1971 data. We therefore conclude that the observed difference in our regression results for 1969-70 and 1971 derive from policy and not from an incorrect specification of fundamental relationships.

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* Although all other possible shifts in structure were also examined for Eugene and Salem (1969 v. 1970, 1969 v. 1971, 1969 v. 1970-71, and 1970 v. 1971), none proved significant at the 10 percent level.

### D.4. Implications and Tentative Conclusions

The objective of a smoke management policy is the minimization of the harmful effects associated with the smoke produced by the open burning of a given total acreage of agricultural fields. Operationally, smoke management as practiced by the DEQ attempts to minimize visibility losses attributable to field burning smoke in Eugene and Salem. Smoke management thus minimizes rather than eliminates visibility losses in certain areas, while undoubtedly increasing visibility losses in other areas. Viewed most broadly the foregoing results clearly establish that smoke management can successfully reduce visibility losses from field burning smoke in Eugene and Salem. Moreover, our results suggest that reductions in acres burned, especially acres burned between Salem and Eugene would greatly facilitate successful smoke management.

In our second annual report we employed regression results for Eugene in 1969 and 1970 to study the effectiveness of the 1970 DEQ burning program. There we concluded that probably not more than half of the 1969-70 improvement in Eugene visibility was attributable to the reduction in acres burned in the Valley under northerly wind conditions. Moreover, perhaps as much as two-thirds of the 1969-70 improvement in Eugene visibility resulted from the controlled 1970 geographic distribution of acres-burned according to predicted late morning and afternoon meteorological conditions. All of which suggested that perhaps most of the success of the 1970 DEQ burning program and schedule derived from (a) accurate meteorological forecasts and (b) control over the geographic distribution of acres-burned rather than the reduction in acres-burned.

Here, in contrast, we conclude by reporting equations which represent pollution production functions for Eugene and Salem. Such functions are required to predict the impact of alternative burning control policies. The desired functions were obtained by solving the following equations for $a_1$ and $a_2$:

$$\bar{V}_{71} = \bar{V}^* + a_1 \bar{A}_{71} + a_2 A_{71}^2$$

$$\eta = \frac{\dfrac{\partial V_{71}}{\partial A_{71}}}{\dfrac{\bar{V}_{71}}{\bar{A}_{71}}} = \frac{a_1 + 2a_2 A_{71}}{\dfrac{\bar{V}_{71}}{\bar{A}_{71}}}$$

where $\bar{V}_{71}$ = mean 1971 minimum daylight visibility

$\bar{V}^*$ = estimated mean minimum daylight visibility with no relevant acres burned

$\bar{A}_{71}$ = mean 1971 relevant acres burned

$\eta$ = estimated elasticity of minimum daylight visibility with respect to carefully regulated relevant acres burned.

This procedure explicitly assumes that there exists a continuous, smooth, inverse relationship between minimum daylight visibility and relevant acres burned which passes through $\bar{V}_{71}$ and $\bar{A}_{71}$ and has a curvature consistent with the log - log functional form employed in our multiple regression statistical analysis. We expected and did obtain equations where $a_1 < 0$ and $a_2 > 0$.

The upper half of Table D.17 presents our estimated equations for the pollution production functions associated with carefully regulated field burning for Eugene and Salem under northerly and southerly wind conditions. (The lower half of Table D.17 presents the data which, together with $\bar{V}^*$, were employed to calculate $a_1$ and $a_2$.) V* was estimated for Eugene and Salem under northerly wind conditions by calculating mean minimum daylight visibility on days in August (the heart of the burning season) 1967 when the Oregon State Fire Marshall prohibited all burning.

In the case of Salem under southerly wind conditions, however, careful study suggested that 14.0 miles would be a "reasonable" estimate of minimum daylight visibility with no burning. Otherwise the data employed to calculate $a_1$ and $a_2$ were obtained from our 1971 and 1970-71 (or 1969-70-71) regression results for estimates of N and mean observed 1971 minimum daylight visibility and relevant acres burned. Since the 1971 DEQ burning program was in fact reasonably successful in minimizing the visibility losses associated with open field burning, our procedure for calculating the equations presented in Table D.17 implies that the reported equations specify pollution production functions that approximate the functions truly relevant for estimating the benefits of reducing acres burned in the Willamette Valley under different wind conditions.* Consequently, these equations underlie the benefit estimates reported in the main text of this report.

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* Additional evidence supporting the reasonableness of the functions reported in Table D.17 was obtained when we compared our direct regression estimates of visibility elasticities with respect to acres burned in 1970 with those calculated at mean 1970 acres-burned with the functions in Table D.17. The calculated elasticity estimates were in no instance as much as 5 percent different from the direct elasticity estimates. We therefore conclude that our pollution production function equations appear "reasonable".

## Table D.1
## Model I Regression Results For Eugene Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| Regression Coefficients, Etc. | | | |
| Constant | 2.458 | 0.976 | 2.003 |
| North acres burned | -0.304[b] | 0.287X | -0.140 |
| | (2.050) | (0.751) | (0.962) |
| South acres burned | -0.332[a] | -0.352[d] | -0.341[a] |
| | (3.970) | (1.512) | (4.277) |
| Visibility at 7 a.m. | 0.269[c] | 0.060 | 0.262[b] |
| | (1.912) | (0.173) | (2.064) |
| Number of observations | 40 | 16 | 56 |
| $\bar{R}^2$ | 0.520 | - | 0.368 |
| F-statistic | 15.860[a] | 0.806 | 12.418[a] |
| Beta Coefficients | | | |
| North acres burned | 0.531 | 0.288X | 0.284 |
| South acres burned | 1.028 | 0.573 | 1.261 |
| Visibility at 7 a.m. | 0.495 | 0.065 | 0.608 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 10 percent level.
[d] Significant at the 20 percent level.
[e] Significant at the 30 percent level.

### Table D.2
### Model II Regression Results For Eugene

### Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| Regression Coefficients, Etc. | | | |
| Constant | 13.967 | 9.059 | 10.556 |
| North acres burned | -0.312[b] | 0.235X | -0.154[e] |
| | (2.267) | (0.603) | (1.094) |
| South acres burned | -0.314[a] | -0.322[d] | -0.341[a] |
| | (4.018) | (1.353) | (4.429) |
| Visibility at 7 a.m. | 0.244[c] | -0.138X | 0.195[d] |
| | (1.862) | (0.329) | (1.542) |
| Inversion height at 4 p.m. | -3.928[b] | -2.647 | -2.877[b] |
| | (2.604) | (0.869) | (2.183) |
| Number of observations | 40 | 16 | 56 |
| $\bar{R}^2$ | 0.588 | - | 0.414 |
| F-statistic | 15.502[a] | 0.781 | 11.180[a] |
| Beta Coefficients | | | |
| North acres burned | 0.545 | 0.231X | 0.311 |
| South acres burned | 0.966 | 0.518 | 1.261 |
| Visibility at 7 a.m. | 0.447 | 0.126X | 0.439 |
| Inversion height at 4 p.m. | 0.626 | 0.333 | 0.621 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 10 percent level.
[d] Significant at the 20 percent level.
[e] Significant at the 30 percent level.

### Table D.3
### Model III Regression Results For Eugene Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| **Regression Coefficients, Etc.** | | | |
| Constant | 14.608 | 9.334 | 10.549 |
| North acres burned | -0.312[b]<br>(2.272) | 0.261X<br>(0.568) | -0.176[e]<br>(1.237) |
| South acres burned | -0.296[a]<br>(3.727) | -0.332[e]<br>(1.264) | -0.325[a]<br>(4.154) |
| Visibility at 7 a.m. | 0.224[c]<br>(1.709) | -0.131X<br>(0.297) | 0.166[e]<br>(1.287) |
| Inversion height at 4 p.m. | -4.229[a]<br>(2.773) | -2.735<br>(0.837) | -2.926[b]<br>(2.224) |
| Wind speed at 4 p.m. | 0.222[e]<br>(1.140) | -0.075X<br>(0.123) | 0.211[e]<br>(1.101) |
| Number of observations | 40 | 16 | 56 |
| $\bar{R}^2$ | 0.589 | - | 0.416 |
| F-statistic | 12.767[a] | 0.572 | 9.223[a] |
| **Beta Coefficients** | | | |
| North acres burned | 0.540 | 0.228X | 0.351 |
| South acres burned | 0.892 | 0.507 | 1.180 |
| Visibility at 7 a.m. | 0.409 | 0.119X | 0.366 |
| Inversion height at 4 p.m. | 0.664 | 0.336 | 0.632 |
| Wind speed at 4 p.m. | 0.273 | 0.049X | 0.313 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.4
## Model IV Regression Results For Eugene Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| **Regression Coefficients, Etc.** | | | |
| Constant | 13.697 | 8.880 | 10.515 |
| North acres burned | -0.313[b]<br>(2.241) | 0.246X<br>(0.541) | -0.154[e]<br>(1.080) |
| South acres burned | -0.315[a]<br>(3.979) | -0.325[e]<br>(1.272) | -0.342[a]<br>(4.371) |
| Visibility at 7 a.m. | 0.244[c]<br>(1.845) | -0.150X<br>(0.305) | 0.195[d]<br>(1.522) |
| Inversion height at 4 p.m. | -3.886[b]<br>(2.536) | -2.647<br>(0.829) | -2.871[b]<br>(2.150) |
| Atmospheric stability at 4 p.m. | 0.151<br>(0.349) | 0.164<br>(0.157) | 0.025<br>(0.050) |
| Number of observations | 40 | 16 | 56 |
| $\bar{R}^2$ | 0.575 | - | 0.402 |
| F-statistic | 12.115[a] | 0.569 | 8.769[a] |
| **Beta Coefficients** | | | |
| North acres burned | 0.545 | 0.217X | 0.310 |
| South acres burned | 0.968 | 0.511 | 1.256 |
| Visibility at 7 a.m. | 0.449 | 0.122X | 0.438 |
| Inversion height at 4 p.m. | 0.617 | 0.333 | 0.618 |
| Atmospheric stability at 4 p.m. | 0.085 | 0.023 | 0.014 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.5
## Model V Regression Results For Eugene Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| **Regression Results, Etc.** | | | |
| Constant | 14.361 | 9.119 | 10.531 |
| North acres burned | -0.312[b] | 0.279X | -0.175[e] |
| | (2.244) | (0.513) | (1.221) |
| South acres burned | -0.297[a] | -0.337[e] | -0.325[a] |
| | (3.688) | (1.179) | (4.094) |
| Visibility at 7 a.m. | 0.255[c] | -0.148X | 0.166[e] |
| | (1.693) | (0.284) | (1.272) |
| Inversion height at 4 p.m. | -4.189[b] | -2.742 | -2.924[b] |
| | (2.701) | (0.795) | (2.192) |
| Wind speed at 4 p.m. | 0.220[e] | -0.082X | 0.211[e] |
| | (1.113) | (0.126) | (1.089) |
| Atmospheric stability at 4 p.m. | 0.135 | 0.219 | 0.011 |
| | (0.312) | (0.071) | (0.022) |
| Number of observations | 40 | 16 | 56 |
| $\bar{R}^2$ | 0.578 | - | 0.404 |
| F-statistic | 10.373[a] | 0.430 | 7.532[a] |
| **Beta Coefficients** | | | |
| North acres burned | 0.544 | 0.217X | 0.350 |
| South acres burned | 0.894 | 0.499 | 1.175 |
| Visibility at 7 a.m. | 0.411 | 0.120X | 0.365 |
| Inversion height at 4 p.m. | 0.644 | 0.337 | 0.629 |
| Wind speed at 4 p.m. | 0.270 | 0.053X | 0.312 |
| Atmospheric stability at 4 p.m. | 0.076 | 0.030 | 0.006 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.6
## Model I Regression Results For Salem Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| **Regression Coefficients, Etc.** | | | |
| Constant | 0.795 | 2.124 | 1.097 |
| North acres burned | -0.172[d]<br>(1.451) | -0.305[d]<br>(1.519) | -0.201[c]<br>(1.935) |
| Visibility at 7 a.m. | 0.599[a]<br>(3.953) | -0.124X<br>(0.456) | 0.436<br>(3.214) |
| Number of observations | 46 | 18 | 64 |
| $\bar{R}^2$ | 0.255 | - | 0.156 |
| F-statistic | 9.435[a] | 1.285 | 7.463[a] |
| **Beta Coefficients** | | | |
| North acres burned | 0.383 | 0.376 | 0.517 |
| Visibility at 7 a.m. | 1.044 | 0.113X | 0.859 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 10 percent level.
[d] Significant at the 20 percent level.
[e] Significant at the 30 percent level.

## Table D.7
## Model II Regression Results For Salem Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| Regression Results, Etc. | | | |
| Constant | 10.596 | 0.455 | 4.573 |
| North acres burned | -0.138[e] | -0.289[d] | -0.198[c] |
| | (1.215) | (1.349) | (1.913) |
| Visibility at 7 a.m. | 0.478[a] | -0.090X | 0.385[b] |
| | (3.120) | (0.298) | (2.666) |
| Inversion height at 4 p.m. | -3.333[b] | 0.537X | -1.168 |
| | (2.330) | (0.298) | (1.020) |
| Number of observations | 46 | 18 | 64 |
| $\bar{R}^2$ | 0.324 | - | 0.157 |
| F-statistic | 8.747[a] | 0.834 | 5.326[a] |
| Beta Coefficients | | | |
| North acres burned | 0.306 | 0.345 | 0.511 |
| Visibility at 7 a.m. | 0.785 | 0.076X | 0.712 |
| Inversion height at 4 p.m. | 0.586 | 0.076X | 0.273 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.8
## Model III Regression Results For Salem Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| **Regression Results, Etc.** | | | |
| Constant | 11.522 | 0.929 | 4.611 |
| North acres burned | -0.119 | -0.275[e] | -0.201[c] |
| | (1.044) | (1.194) | (1.935) |
| Visibility at 7 a.m. | 0.383[b] | -0.104X | 0.344[b] |
| | (2.227) | (0.326) | (2.270) |
| Inversion height at 4 p.m. | -3.708[b] | 0.394X | -1.213[e] |
| | (2.544) | (0.199) | (1.058) |
| Wind speed at 4 p.m. | 0.243[e] | -0.078X | 0.156 |
| | (1.197) | (0.223) | (0.933) |
| Number of observations | 46 | 18 | 64 |
| $\bar{R}^2$ | 0.331 | - | 0.155 |
| F-statistic | 6.986 | 0.595 | 4.203[a] |
| **Beta Coefficients** | | | |
| North acres burned | 0.261 | 0.316 | 0.518 |
| Visibility at 7 a.m. | 0.557 | 0.086X | 0.607 |
| Inversion height at 4 p.m. | 0.637 | 0.053X | 0.283 |
| Wind speed at 4 p.m. | 0.300 | 0.059X | 0.249 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 10 percent level.
[d] Significant at the 20 percent level.
[e] Significant at the 30 percent level.

### Table D.9
### Model IV Regression Results For Salem Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| Regression Results, Etc. | | | |
| Constant | 10.589 | 0.931 | 4.518 |
| North acres burned | -0.138[e] | -0.272[e] | -0.199[c] |
| | (1.202) | (1.218) | (1.903) |
| Visibility at 7 a.m. | 0.477[a] | -0.097X | 0.382[b] |
| | (3.035) | (0.309) | (2.599) |
| Inversion height at 4 p.m. | -3.340[b] | 0.771X | -1.171 |
| | (2.302) | (0.400) | (1.014) |
| Atmospheric stability at 4 p.m. | 0.030 | 0.655 | 0.069 |
| | (0.070) | (0.463) | (0.161) |
| Number of observations | 46 | 18 | 64 |
| $\bar{R}^2$ | 0.308 | - | 0.143 |
| F-statistic | 6.406[a] | 0.644 | 3.936[a] |
| Beta Coefficients | | | |
| North acres burned | 0.306 | 0.320 | 0.513 |
| Visibility at 7 a.m. | 0.773 | 0.081X | 0.700 |
| Inversion height at 4 p.m. | 0.586 | 0.105X | 0.273 |
| Atmospheric stability at 4 p.m. | 0.018 | 0.122 | 0.043 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.10
## Model V Regression Results For Salem Under Northerly Wind Conditions

| | 1969-70 | 1971 | 1969-70-71 |
|---|---|---|---|
| Regression Results, Etc. | | | |
| Constant | 11.514 | 0.507 | 4.557 |
| North acres burned | -0.120 | -0.262[e] | -0.202[c] |
| | (1.034) | (1.093) | (1.924) |
| Visibility at 7 a.m. | 0.381[b] | -0.107X | 0.341[b] |
| | (2.169) | (0.323) | (2.213) |
| Inversion height at 4 p.m. | -3.715[b] | 0.651X | -1.216[e] |
| | (2.513) | (0.305) | (1.051) |
| Wind speed at 4 p.m. | 0.243[e] | -0.060X | 0.156 |
| | (1.183) | (0.164) | (0.925) |
| Atmospheric stability at 4 p.m. | 0.031 | 0.626 | 0.068 |
| | (0.072) | (0.423) | (0.158) |
| Number of observations | 46 | 18 | 64 |
| $\bar{R}^2$ | 0.314 | - | 0.140 |
| F-statistic | 5.454[a] | 0.482 | 3.312[b] |
| Beta Coefficients | | | |
| North acres burned | 0.262 | 0.299 | 0.519 |
| Visibility at 7 a.m. | 0.549 | 0.088X | 0.597 |
| Inversion height at 4 p.m. | 0.637 | 0.083X | 0.283 |
| Wind speed at 4 p.m. | 0.300 | 0.045X | 0.249 |
| Atmospheric stability at 4.p.m. | 0.018 | 0.116 | 0.043 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.11
## Model I Regression Results For Salem Under Southerly Wind Conditions

| | 1969-70 | 1970-71 | 1969-70-71 |
|---|---|---|---|
| Regression Coefficients, Etc. | | | |
| Constant | -0.842 | 0.740 | 0.829 |
| South acres burned | -0.113[e] | -0.057 | -0.083[e] |
| | (1.219) | (0.643) | (1.243) |
| Visibility at 7a.m. | 0.433[c] | 0.374[c] | 0.373[c] |
| | (1.764) | (1.790) | (2.005) |
| Number of observations | 17 | 18 | 26 |
| $\bar{R}^2$ | 0.107 | 0.022 | 0.079 |
| F-statistic | 1.965 | 1.809 | 2.690 |
| Beta Coefficients | | | |
| South acres burned | 0.284 | 0.172 | 0.350 |
| Visibility at 7a.m. | 0.425 | 0.478 | 0.564 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 10 percent level.
[d] Significant at the 20 percent level.
[e] Significant at the 30 percent level.

## Table D.12
## Model II Regression Results For Salem Under Southerly Wind Conditions

| | 1969-70 | 1970-71 | 1969-70-71 |
|---|---|---|---|
| Regression Coefficients, Etc. | | | |
| Constant | 22.647 | 13.082 | 15.182 |
| South acres burned | -0.273[a] | -0.182[c] | -0.190[a] |
| | (3.971) | (1.990) | (2.976) |
| Visibility at 7 a.m. | 0.187[e] | 0.285[d] | 0.284[c] |
| | (1.128) | (1.556) | (1.565) |
| Inversion height at 4 p.m. | -7.218[a] | -4.049[b] | -4.768[a] |
| | (4.631) | (2.490) | (3.394) |
| Number of observations | 17 | 18 | 26 |
| $\bar{R}^2$ | 0.663 | 0.270 | 0.367 |
| F-statistic | 10.616[a] | 3.691[b] | 6.454[a] |
| Beta Coefficients | | | |
| South acres burned | 0.687 | 0.458 | 0.694 |
| Visibility at 7 a.m. | 0.187 | 0.358 | 0.423 |
| Inversion height at 4 p.m. | 0.849 | 0.573 | 0.791 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 10 percent level.
[d] Significant at the 20 percent level.
[e] Significant at the 30 percent level.

## Table D.13
## Model III Regression Results For Salem Under Southerly Wind Conditions

| | 1969-70 | 1970-71 | 1969-70-71 |
|---|---|---|---|
| Regression Coefficients, Etc. | | | |
| Constant | 21.979 | 14.499 | 16.442 |
| South acres burned | -0.274[a] | -0.160[d] | -0.182[a] |
| | (3.837) | (1.620) | (2.786) |
| Visibility at 7 a.m. | 0.179 | 0.281 | 0.277 |
| | (1.028) | (1.506) | (1.751) |
| Inversion height at 4 p.m. | -7.018[a] | -4.498[b] | -5.156 |
| | (4.137) | (2.533) | (3.407) |
| Wind speed at 4 p.m. | 0.091 | -0.182X | -0.143X |
| | (0.389) | (0.701) | (0.739) |
| Number of observations | 17 | 18 | 26 |
| $\bar{R}^2$ | 0.640 | 0.238 | 0.352 |
| F-statistic | 7.437[a] | 2.791 | 4.877 |
| Beta Coefficients | | | |
| South acres burned | 0.689 | 0.380 | 0.657 |
| Visibility at 7 | 0.176 | 0.353 | 0.413 |
| Inversion height at 4 p.m. | 0.825 | 0.594 | 0.803 |
| Wind speed at 4 p.m. | 0.067 | 0.164X | 0.174X |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.14
## Model IV Regression Results For Salem Under Southerly Wind Conditions

| | 1969-70 | 1970-71 | 1969-70-71 |
|---|---|---|---|
| Regression Coefficients, Etc. | | | |
| Constant | 27.131 | 12.386 | 15.179 |
| South acres burned | -0.266[a] | -0.190[c] | -0.190[a] |
| | (4.055) | (1.957) | (2.876) |
| Visibility at 7 a.m. | 0.165 | 0.283[d] | 0.284[c] |
| | (1.035) | (1.496) | (1.768) |
| Inversion height at 4 p.m. | -8.546[a] | -3.829[b] | -4.767[a] |
| | (4.934) | (2.138) | (3.087) |
| Atmospheric stability at 4 p.m. | -0.321X | 0.089 | 0.000 |
| | (1.035) | (0.353) | (0.002) |
| Number of observations | 17 | 18 | 26 |
| $\bar{R}^2$ | 0.696 | 0.217 | 0.335 |
| F-statistic | 9.326[a] | 2.627 | 4.621[a] |
| Beta Coefficients | | | |
| South acres burned | 0.669 | 0.465 | 0.686 |
| Visibility at 7 a.m. | 0.162 | 0.355 | 0.422 |
| Inversion height at 4 p.m. | 1.005 | 0.508 | 0.737 |
| Atmospheric stability at 4 p.m. | 0.266X | 0.355 | 0.000 |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

## Table D.15
## Model V Regression Results For Salem Under Southerly Wind Conditions

| | 1969-70 | 1970-71 | 1969-70-71 |
|---|---|---|---|
| **Regression Coefficients, Etc.** | | | |
| Constant | 28.000 | 14.877 | 17.396 |
| South acres burned | -0.265[a] | -0.155[d] | -0.177[b] |
| | (3.856) | (1.331) | (2.576) |
| Visibility at 7 a.m. | 0.169 | 0.282[d] | 0.279[c] |
| | (1.010) | (1.448) | (1.725) |
| Inversion height at 4 p.m. | -8.805[a] | -4.617[c] | -5.451[a] |
| | (4.243) | (2.028) | (3.065) |
| Wind speed at 4 p.m. | -0.064X | -0.200X | -0.174X |
| | (0.255) | (0.586) | (0.797) |
| Atmospheric stability at 4 p.m. | -0.064X | -0.030X | -0.087X |
| | (1.390) | (0.090) | (0.335) |
| Number of observations | 17 | 18 | 26 |
| $\bar{R}^2$ | 0.671 | 0.169 | 0.322 |
| F-statistic | 6.840[a] | 2.064 | 3.759[b] |
| **Beta Coefficients** | | | |
| South acres burned | 0.667 | 0.325 | 0.620 |
| Visibility at 7 a.m. | 0.137 | 0.353 | 0.415 |
| Inversion height at 4 p.m. | 1.035 | 0.494 | 0.738 |
| Wind speed at 4 p.m. | 0.047X | 0.143X | 0.192X |
| Atmospheric stability at 4 p.m. | 0.290X | 0.022X | 0.008X |

Note: Figures in parentheses are t-statistics, and X indicates that the coefficient has a theoretically unanticipated sign.

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 10 percent level.

[d] Significant at the 20 percent level.

[e] Significant at the 30 percent level.

### Table D.16
### Simple Correlation Coefficients Between Acres Burned in the Northern and Southern Sections of the Willamette Valley, Inversion Height at 4 p.m., and Visibility at 7 a.m., Eugene and Salem, 1969, 1970, 1969-70, and 1971.

| | Acres Burned in Willamette Valley | |
|---|---|---|
| | North Valley | South Valley |
| **Eugene** | Visibility at 7 a.m. | |
| 1969 | -0.316 | -0.106 |
| 1970 | 0.142 | -0.620 |
| 1969-70 | -0.090 | -0.394 |
| 1971 | 0.249Z | 0.404Z |
| | Inversion Height at 4 p.m. | |
| 1969 | 0.136 | 0.005 |
| 1970 | -0.126Z | 0.280 |
| 1969-70 | 0.024 | 0.130 |
| 1971 | -0.210Z | -0.164Z |
| **Salem** | Visibility at 7 a.m. | |
| 1969 | -0.196 | |
| 1970 | 0.010Z | |
| 1969-70 | -0.087 | |
| 1971 | -0.037 | |
| | Inversion Height at 4 p.m. | |
| 1969 | 0.204 | |
| 1970 | 0.079 | |
| 1969-70 | 0.149 | |
| 1971 | -0.248Z | |

Note: Z indicates that the sign of the correlation coefficient is consistent with a positive field burning control policy.

## Table D.17
## Equations For Open-Field-Burning Pollution Production Functions In The Willamette Valley

| | Eugene, North Wind Conditions | Salem, North Wind Conditions | Salem, South Wind Conditions |
|---|---|---|---|
| $\overline{V}^*$ | 11.30 | 13.80 | 14.00 |
| $a_1$ | $-4.18 \times 10^{-3}$ | $-2.53 \times 10^{-3}$ | $-2.33 \times 10^{-3}$ |
| $a_2$ | $7.13 \times 10^{-7}$ | $1.42 \times 10^{-7}$ | $2.80 \times 10^{-7}$ |
| $\overline{V}_{71}$ | 8.04 | 10.67 | 7.75 |
| $\overline{A}_{71}$ | 926 South Acres | 1337 North Acres | 4710 South Acres |
| $\eta$ | -0.33[a] | -0.27[b] | -0.19[c] |

Note: $\overline{V}^*$, $a_1$, and $a_2$ obtained as described in text.

[a] Tables D.2 and D.3

[b] Tables D.8 and D.9

[c] Table D.12

# APPENDIX E

## THE DETERMINANTS OF AGRICULTURAL LAND VALUES IN THE WILLAMETTE VALLEY

This appendix reports the results of a statistical investigation of the determinants of agricultural land values in the Willamette Valley. Primary emphasis in the study was given to the determinants of the intra- and inter-county structure of land values in the eight Willamette Valley counties where substantial quantities of grass seed are raised. The eight counties purposely selected for inter-county study are Benton, Clackamas, Lane, Linn, Marion, Polk, Washington, and Yamhill. In contrast, the particular 72 grass seed operations included in our land value study constitute a subset of a larger sample of seed operations from which we could determine the ownership of 161 parcels (at different locations) in seed production during 1970 and thereby secure county assessment records for each parcel.* This subset of operations permitted intensive intra- and inter-county study of land values only for Benton, Linn, and Marion Counties. Fortunately, this appears quite appropriate because Linn and Benton Counties are major producers of ryegrass, while Marion County leads all other Oregon counties in the production of bentgrass, red fescue, and chewing fescue. These seed varieties are among those that Oregon dominates the nation in production.** The statistical results reported therefore encompass the geographical area of concern quite well.

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* The large sample was selected by means of two-stage sampling technique for a detailed industrial-organization-type study of the Willamette Valley seed industry. Within each county seed operations were selected at random. The analysis of data obtained from the large sample provides much of the information concerning resource organization, cost structures, levels of resource utilization, farm sizes, and managerial objectives in the Willamette Valley seed industry presented elsewhere in this report. For additional details concerning the industry, see Douglas E. Fisher, *An Economic Analysis of Farms Producing Grass Seed in the Willamette Valley, With Special Attention to the Cultural Practice of Field Burning* (unpublished Ph.D. dissertation, Oregon State University, 1972).

** Middlemiss, W. E. and R. O. Coppedge, *Oregon's Grass and Legume Seed Industry in Economic Perspective*, Special Report 284, Cooperative Extension Service, Oregon State University, Corvallis, Oregon. April 1970.

Here, least-squares multiple-regression analysis provides the analytical tool for our empirical investigation of the determinants of both agricultural land market values and agricultural land value differentials. Land value differentials are defined as the difference between the market and farm use values, where farm use value equals the capitalized value of the assessor's estimate of the rent at which the land could presently be leased. The determinants of land value differentials, as well as market values, are investigated here because such differentials are large, positive, exhibit greater variance than market values per acre, and necessarily reflect the higher future earnings anticipated from Willamette Valley land now in agricultural use.

## E.1 The Model

The basic hypothesis of our model is that the market value of any parcel of agricultural land depends on the capitalized value of the parcel's current and expected future net earnings. Of course, since current and future uses of any given parcel of land are not likely to be the same in a rapidly urbanizing area, current land values are unlikely to be closely related to current net earnings. Such land would generally be anticipated to be converted to new agricultural or non-agricultural uses in the future, and a parcel's expected earnings in those new uses would be the major determinants of the parcel's current market value. Therefore, our basic hypothesis requires reformulation for purposes of testing.

Recalling that land now in agricultural use may remain in agricultural use or be converted to non-agricultural use at some point in the future, at least two independent variables (or indices) would appear required "to capture" the dual influence of these possibilities on current land values. To be precise, we hypothesize that current and expected future earnings in agricultural uses are directly related to a consistent and well-defined index of soil quality, while expected future earnings in non-agricultural uses are directly related to the relative accessibility of land parcels to nearby urban centers. Although neither of these hypotheses is particularly unusual when compared to those made in other studies of agricultural land values, the particular soil quality index selected and the absence of data aggregation of the usual sort jointly distinguish this research effort from those undertaken previously.

Dealing first with data aggregation and future conversion to non-agricultural uses, we follow previous studies by measuring the accessibility of land parcels in terms of highway distance to the nearest town with a population over 1,000 but do so for each of the 161 different parcels of land in our sample of 72 farms. Previous investigations, however, have treated farms, even farms composed of non-contiguous land parcels, as the relevant units for study. Consequently, in contrast to these other agricultural land value studies, this one avoids the bias in accessibility measurements introduced when non-contiguous land parcels are treated analytically as if such parcels were contiguous.

Turning now to our hypothesis concerning expected future earnings in agricultural uses, we suggest that future productivity and earnings are more closely and directly related to informed judgment concerning a parecl's soil quality than to the parcel's current net earnings. This seems reasonable because current earnings necessarily reflect basic soil quality, the entreprenuerial effort of the current operator, and current land use. However, given the existence of well-functioning agricultural land and commodity markets, better quality soils would generate higher than average earnings per acre, and vice versa. On such assumptions, therefore, a consistent and well-defined index of soil quality could serve as a proxy for expected future earnings in agricultural uses.

To devise a continuous index of soil quality suitable for use in a multiple-regression study of land values is no simple task. In fact, soil quality is multi-dimensional and would reflect, in combination, soil texture, depth of surface soil, nature of subsoil, fertility, etc. Fortunately for present purposes, agricultural land in the Willamette Valley is typically assessed in terms of its "farm use value," which equals the capitalized value of the county assessor's estimate (for assessment purposes only) of the rent at which it would presently be leased. Given the relatively high level of professional skill demanded of Oregon assessors, as well as the requirement that he treat properties uniformly, this rent estimate provides a consistent and continuous index of soil quality based on informed judgment. Moreover, the assessor's judgment necessarily reflects, albeit imperfectly, the weights the market presently establishes on the various dimensions of soil quality.

Finally, it should be noted that the degree of association between the accessibility (or "urban influence") variables and market values are expected to vary among counties according to the county's present urbanization and the importance attached to future conversion of agricultural land to urban uses by different assessors. For this reason, some experimentation with dummy variables reflecting county urbanization seemed appropriate and is reported here.

## E.2 Statistical Results

Three variants of our basic model have been tested against agricultural land market value and differential value data for Benton, Linn, and Marion Counties individually and jointly, as well as for the eight Willamette Valley counties together. These variants differ from one another in terms of their respective specifications of the independent variables and the assumed functional forms assumed for analysis. The model variants are as follows:

I. $V = V_I(SQ, DT)$

II. $\text{Log}V = V_{II}(\text{Log } SQ, \text{Log } DT)$

III. $V = V_{III}(SQ, DT, D_1, D_2)$

where V = assessed market value per acre or assessed farm use value, SQ = current rent per acre, i.e., our index of soil quality, DT = distance to nearest town with population over 1,000, $D_1$ = dummy variable equal to 1 if population of the nearest town is greater than 1,000 but less than 10,000 and zero otherwise, and $D_2$ = dummy variable equal to 1 if the population of the nearest town is greater than 10,000 but less than 20,000 and zero otherwise.

Tables E.1 through E.6 report our regression results for model variants with agricultural land market values per acre as the dependent variable, while Tables E.7 through E.11 present the results obtained with land value differentials per acre as the dependent variable.

With regard to our market value results, it is important to note that all estimated regression coefficients reported in Tables E.1 - E.6 have the expected signs and support the hypotheses of our basic model.* Moreover, Tables E.3 and E.4 indicate that model variant II performs exceedingly well when judged by the usual statistical tests, particularly when one compares its performance with that of variants I and III when tested on combined three and eight county data. In terms of goodness of fit as measured by $R^2$ and the F-statistic, model variant II performs better than either variant I or III, and both estimated regression coefficients are statistically significant at the one percent level and properly signed.

Two features of the regression results deserve special comment. First, Marion County's relatively large constant terms and distance-to-town t statistics are consistent with the hypothesis that urbanization has had a greater influence on agricultural land values there than in Benton and Linn Counties. In fact, if urbanization is measured by aggregate county population, population of the largest city in the county, or total retail sales, Marion County would be classified as more urbanized than either Benton or Linn Counties. Second, for model variant II, the size and statistical significance of our soil quality regression coefficients is relatively greater and the distance-to-town coefficient relatively smaller for Linn than for Benton and Marion Counties. Such results are consistent with the hypothesis that Linn County land has the lowest potential convertibility to non-seed agricultural or non-agricultural uses among the three counties. Qualitative evidence in support of this hypothesis derives from (1) the poorer quality soil in Linn as opposed to Benton and Marion Counties and (2) the lesser present, and hence forecast future, urbanization of Linn County. Consequently, model variant II (see Table E.3 and E.4) performs rather well with agricultural land market values per acre as the dependent variable.

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* Since dummy variables are essentially intercept shifters, no hypotheses with regard to their signs are supported or rejected by the results reported in Tables E.5 and E.6.

Turning next to our findings when agricultural land value differentials are the dependent variable, Tables E.7 through E.11 report poorer regression results than those discussed above. This general finding cannot be regarded as surprising, however, because land value differentials (1) have a much greater variance than market values and (2) presumably reflect other factors than those associated with current agricultural use. Without an increase in the number of independent variables, therefore, one would reasonably expect less satisfactory performance of our basic model. Nonetheless, the following features of our results are noteworthy.

First, as before, model variant II performs better than variants I and III. Tables E.9 and E.10 show all estimated regression coefficients have their theoretically anticipated signs and relatively uniform $R^2$ and F-statistics for model variant II. The multiplicative functional form assumed for variant II once again appears more appropriate than the additive form most often used in land value investigations. Of course, the high degree of statistical significance for the distance-to-town variable supports our basic hypothesis that land parcels located more closely to existing urban areas are more likely to be converted to non-agricultural uses in the future. Additional evidence in support of this hypothesis may be derived from a comparison of the size of the distance-to-town regression coefficients in Tables E.3, E.4, E.9, and E.10. Such comparisons indicate that the coefficients estimated with differentials as the dependent variable are approximately twice the size of the coefficients estimated with market value data. Finally, the lack of statistical significance for the estimated soil-quality regression coefficients in Tables E.9 and E.10 indicate that agricultural land value differentials in the Willamette Valley are apparently not "explained" by either intra- or inter-county variation in potential productivity in agricultural uses.

Since land value differentials are calculated in a fashion to minimize, though undoubtedly not eliminate, the influence of current earnings from agricultural use, our land value differential regression results usefully supplement the market value results and lead us to the following tentative conclusions. First, the structure of agricultural land values in the Willamette Valley reflect urban influences in much the same fashion as location theory would predict and as other studies have discovered elsewhere. Second, prospective urbanization and urban influences rather than prospective continued agricultural use dominate the structure of agricultural land values throughout the Willamette Valley.

## E.3 Conclusion

For the purposes of measuring the costs associated with control of open field burning in the Willamette Valley, the most important results obtained are those reported in Table E.4. Despite inter-county variation in the relative importance of the factors that statistically account for variations in agricultural land values, our basic model performs rather well when tested against data from (1) the three major and (2) all eight seed-producing counties. These results suggest the existence of a relatively "well-behaved" agricultural land value surface extending across county boundaries in the Willamette Valley.

## Table E.1

## Market Values

## Regression Results: Model I For Benton, Linn, and Marion Counties Separately

| | Benton | Linn | Marion |
|---|---|---|---|
| Constant | 268.1636 | 181.1212 | 697.5259 |
| Soil quality | 13.4541[a] | 10.8166[a] | 1.8875 |
| | (8.526) | (7.041) | (.061) |
| Distance to town | 23.1971[a] | -13.9725[b] | -62.7178[a] |
| | (-4.654) | (-2.451) | (-6.783) |
| $R^2$ | .7859 | .5834 | .7632 |
| $\bar{R}^2$ | .7733 | .5667 | .7450 |
| F-statistic | 62.4034 | 35.0103 | 41.9099 |
| Degrees of freedom | 34 | 50 | 26 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

# Table E.2

## Market Values

Regression Results: Model I for Benton, Linn and Marion Counties and for all Counties.

| | Three Counties | All Counties |
|---|---|---|
| Constant | 312.8117 | 233.5416 |
| Soil quality | 8.7354[a]<br>(7.028) | 10.9942[a]<br>(9.598) |
| Distance to town | -21.9800[a]<br>(-5.616) | -15.1824[a]<br>(-4.409) |
| $R^2$ | .5415 | .4927 |
| $\bar{R}^2$ | .5336 | .4863 |
| F-statistic | 68.4915 | 76.7273 |
| Degrees of freedom | 116 | 158 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.

### Table E.3

### Market Values

### Regression Results: Model II for Benton, Linn and Marion Counties Separately

| | Benton | Linn | Marion |
|---|---|---|---|
| Constant | 2.0676 | 1.6597 | 2.3416 |
| Soil quality | 0.6759[a]<br>(10.154) | 0.7232[a]<br>(10.63) | 0.4872[a]<br>(3.194) |
| Distance to town | -0.4653[a]<br>(-4.599) | -0.1432[a]<br>(2.97) | -0.5691[a]<br>(-4.801) |
| $R^2$ | .8197 | .7479 | .7144 |
| $\bar{R}^2$ | .8091 | .7378 | .6924 |
| F-statistic | 77.2835 | 14.83 | 32.5105 |
| Degrees of freedom | 34 | 50 | 26 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.

## Table E.4

## Market Values

Regression Results: Model II for Benton, Linn and Marion Counties Combined and for all Counties

| | Three Counties | All Counties |
|---|---|---|
| Constant | 1.9587 | 1.8497 |
| Soil quality | 0.5944[a]<br>(10.886) | 0.6333[a]<br>(12.975) |
| Distance to town | -0.2652[a]<br>(-5.625) | -0.1731[a]<br>(-4.695) |
| $R^2$ | .6581 | .5980 |
| $\bar{R}^2$ | .6527 | .5928 |
| F-statistic | 111.6228 | 117.5392 |
| Degrees of freedom | 116 | 158 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.

## Table E.5

## Market Values

Regression Results: Model III for Benton, Linn and Marion Counties Separately.

| | Benton | Linn | Marion |
|---|---|---|---|
| Constant | 133.8253 | 139.1472 | 687.4362 |
| Soil quality | 13.4968[a]<br>(10.398) | 10.6798[a]<br>(6.512) | 1.9988<br>(0.584) |
| Distance to town | -7.0758<br>(-1.236) | -13.5581[b]<br>(-2.313) | -62.2614[a]<br>(-6.223) |
| Dummy 1 | -22.4137<br>(-1.193) | 42.0792<br>(0.867) | 7.2854<br>(0.156) |
| Dummy 2 | 110.8673[a]<br>(3.252) | 58.2341<br>(1.120) | -4.1374<br>(-0.038) |
| $R^2$ | .8643 | .5942 | .7636 |
| $\bar{R}^2$ | .8473 | .5598 | .7242 |
| F-statistic | 50.9357 | 17.5690 | 19.3794 |
| Degrees of freedom | 32 | 48 | 24 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

## Table E.6

### Market Values

Regression Results: Model III for Three Counties; Benton, Linn and Marion Combined.

| | Three Counties |
|---|---|
| Constant | 326.6881 |
| Soil quality | 8.4352[a]<br>(6.583) |
| Distance to town | -22.1400<br>(-5.466) |
| Dummy 1 | -13.0011<br>(-0.515) |
| Dummy 2 | 14.4446<br>(0.432) |
| $R^2$ | .5467 |
| $\bar{R}^2$ | .5278 |
| F-statistic | 34.3711 |
| Degrees of freedom | 114 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.

## Table E.7

## Land Value Differentials

Regression Results: Model I for Benton, Linn and Marion Counties Separately.

| | Benton | Linn | Marion |
|---|---|---|---|
| Constant | 279.9287 | 165.4939 | 768.8398 |
| Soil quality | 2.8872<br>(1.832) | 0.4198<br>(0.265) | -10.1798[a]<br>(-3.4187) |
| Distance to town | -23.9125[a]<br>(-4.804) | -13.1903[b]<br>(-2.240) | -69.7724[a]<br>(-7.8276) |
| $R^2$ | .4972 | .1045 | .7132 |
| $\bar{R}^2$ | .4676 | .0687 | .6911 |
| F-statistic | 16.8120 | 2.9163 | 32.3231 |
| Degrees of freedom | 34 | 50 | 26 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

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### Table E.8

### Land Value Differentials

Regression Results: Model I for Three Counties; Benton, Linn and Marion Combined and for all Counties.

| | Three Counties | All Counties |
|---|---|---|
| Constant | 311.3299 | 234.6726 |
| Soil quality | -2.0002<br>(-1.574) | 0.3904<br>(0.333) |
| Distance to town | -21.2569[a]<br>(-5.311) | -14.9188[a]<br>(-4.229) |
| $R^2$ | .1982 | .1171 |
| $\bar{R}^2$ | .1844 | .1059 |
| F-statistic | 14.3379 | 10.4816 |
| Degrees of freedom | 116 | 158 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.

## Table E.9

## Land Value Differentials

Regression Results: Model II for Benton, Linn and Marion Counties Separately.

| | Benton | Linn | Marion |
|---|---|---|---|
| Constant | 2.6075 | 1.9992 | 2.8629 |
| Soil quality | 0.3180[b]<br>(2.152) | 0.1838<br>(0.997) | 0.3649<br>(0.097) |
| Distance to town | -1.0240[a]<br>(-4.599) | -0.4046[a]<br>(-3.095) | -1.0638[a]<br>(-3.625) |
| $R^2$ | .4828 | .2072 | .4097 |
| $\bar{R}^2$ | .4528 | .1755 | .3643 |
| F-statistic | 15.8718 | 6.5354 | 9.0237 |
| Degrees of freedom | 34 | 50 | 26 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

### Table E.10

### Land Value Differentials

Regression Results: Model II for Three Counties; Benton, Linn and Marion Combined and for all Counties.

| | Three Counties | All Counties |
|---|---|---|
| Constant | 2.3788 | 2.1778 |
| Soil quality | 0.0487<br>(0.361) | 0.1325<br>(1.127) |
| Distance to town | -0.5185[a]<br>(-4.454) | -0.3492[a]<br>(-3.930) |
| $R^2$ | .1730 | .1130 |
| $\bar{R}^2$ | .1588 | .1018 |
| F-statistic | 12.1366 | 10.0744 |
| Degrees of freedom | 116 | 158 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.

## Table E.11

## Land Value Differentials

Regression Results: Model III for Benton, Linn and Marion Counties Separately.

| | Benton | Linn | Marion |
|---|---|---|---|
| Constant | 120.5948 | 130.6073 | 700.1061 |
| Soil quality | 3.1019[b]<br>(2.489) | 0.2898<br>(0.170) | -8.7482[b]<br>(-2.586) |
| Distance to town | -5.4457<br>(-1.006) | 112.8631[b]<br>(-2.115) | -63.3860[a]<br>(-6.415) |
| Dummy 1 | -21.1583<br>(-1.175) | 35.2514<br>(0.700) | 4.5226<br>(0.098) |
| Dummy 2 | 126.4737[a]<br>(4.008) | 49.6798<br>(0.921) | -2.9568<br>(-0.028) |
| $R^2$ | .7147 | .1204 | .6670 |
| $\bar{R}^2$ | .6790 | .0456 | .6115 |
| F-statistic | 20.0400 | 1.6419 | 12.0167 |
| Degrees of freedom | 32 | 48 | 24 |

Note: Figures in parentheses are t-statistics.

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

# APPENDIX F

## DEMAND AND SUPPLY RESPONSE FUNCTIONS FOR GRASS SEEDS RAISED IN THE WILLAMETTE VALLEY

This appendix reports the specification and estimation of demand and supply-response functions for six grass seeds raised in the Willamette Valley. In 1969, these six grass seeds (ryegrass, tall, red, and chewings fescues, Merion-Kentucky bluegrass, and bentgrass) were grown on 85 percent of the acreage devoted to grass seed production in Oregon and provided more than 75 percent of the total value of sales of all grass seeds produced in Oregon.* For these six crops, our best estimates of own-price elasticities of demand range from -1.3 to -2.4, while our best estimates of long-run price elasticities of supply extend from only +1.5 to +2.0. The appendix concludes by presenting the linear demand and supply equations which are the basis of the calculations of changes in producers' and consumers' surpluses reported in the main text of this report.

### F.1 Specification of Demand and Supply-Response Functions

Demand and supply relationships in the grass seed industry are complex and difficult to specify for a variety of reasons. Domestic and world seed prices are determined by the simultaneous of supplies and demand at various marketing levels (form, wholesale, and retail) and outlets (domestic utilization, exports, and carryover) for which only limited, and in some respects unreliable, data exists. More particularly, the perennial nature of many seeds makes specification of supply-response functions difficult, and the fact that most seeds are sold at retail in various mixtures makes a truly adequate specification of independent demand functions quite impossible. Data on grass seed exports is non-existent prior to 1966, while reasonably reliable price and quantity data at the wholesale level is available for twelve or fewer years. Consequently, satisfactory estimates of demand and supply-response functions are possible only at the farm level. Fortunately, however, such estimates provide the minimum information required to measure the social costs of regulating open field burning in the Willamette Valley.

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*Willis E. Middlemiss and Robert O. Coppedge, *Oregon's Grass and Legume Seed Industry in Economic Perspective*, Special Report 284, Cooperative Extension Service, Oregon State University, Corvallis, April 1970, Table 3, p. 3.

In this section we specify and discuss two demand relationships, one for current utilization and the other for ending stocks (i.e., carryover), and an aggregate Oregon supply-response function. It is hypothesized here that, given total commercial availability (i.e., current production plus beginning stocks), the price of seed at the farm level is jointly determined by the interaction of the demands for current utilization and ending stocks. Ideally, of course, foreign and domestic demands would be treated separately, but lack of data precludes this procedure.

Although the estimated relationships are undoubtedly inadequate for truly accurate prediction of future grass seed outputs, prices, disappearance, and carryover, none of our major hypotheses concerning grass seed supply and demand functions have been rejected, and the estimated relationships statistically explain the observed price-quantity data reasonably well. On this basis, however, the estimated demand and supply-response relationships reported here do appear quite adequate for us to accomplish our primary research objective: the measurement of changes in producers' and consumers' surpluses that would have occurred in the recent past if open field burning regulations had been in existence in Oregon.

*Demand for Utilization*. As the introduction to this section has indicated, the unavailability of retail price data for particular grass seeds, the short time-series of wholesale price and quantity data, the considerable importance of stocks carried forward to future years, and very limited export data lead us to specify and estimate demand for utilization functions at the farm level. Moreover, although we fully recognize the desirability of incorporating behavioral variables and relationships to reflect various activities at different marketing levels, limited data availability precluded specification of as complete a model as we wanted. Consequently, we have been required to assume constancy in marketing margins, production coefficients in industries employing grass seeds as inputs, etc.

There are four major hypotheses postulated here concerning the demands for utilization of Oregon grass seeds at the farm level. Each of these hypotheses is equivalent to those commonly tested in econometric studies of demand functions. Here we postulate that demands for seed utilization vary inversely with own prices of seed but directly with prices of substitute seeds. Both of these hypotheses are standard, of course, and empirical experimentation is employed to determine the closest substitute for each forage and turf grass seed. Our third hypothesis concerned the appropriate domestic and foreign demand shift variables for forage and turf grasses. We hypothesized direct relationships between (1) demands for forage seeds and number of cattle in the 12 southern U.S. states and in Canada, West Germany, and France, and (2) demands for turf seeds and the number of housing starts in the United States. Finally, we would not expect consumers to adjust to price and other changes instantaneously --more likely they would adjust their utilization gradually to the desired or equilibrium level. This final hypothesis derives from Nerlove's brilliant insight that we rarely observe equilibrium prices and quantities in competitive markets.*

In sum,your hypotheses concerning demands for utilization can be written as follows:

$$Q^{d*}_{it} = F_i \; (P_{it}, P_{jt}, Z^d_t, Z^f_t, f_{it})$$

where $Q^{d*}_{it}$ = desired or long-run equilibrium quantity-demanded of $i^{\underline{th}}$ grass seed for utilization in year t,

$P_{it}$ = average price of $i^{\underline{th}}$ grass seed received by farmers in year t,

$P_{jt}$ = average price of $j^{\underline{th}}$ grass seed received by farmers in year t, where $j^{\underline{th}}$ seed is a substitute for the $i^{\underline{th}}$ seed,

$Z^d_{it}$ = domestic shift variable: number of cattle in 12 southern states, or number of housing starts in the U.S.

$Z^f_{it}$ = foreign shift variable: number of cattle in Canada, West Germany, and France,

$f_{it}$ = disturbance term

and

$$Q^d_{it} - Q^d_{i,t-1} = \lambda^d_i \; (Q^{d*}_{it} - Q^d_{i,t-1})$$

where $0 < \lambda^d_i < 1$. The first equation expresses our first three hypotheses in a desired or long-run equilibrium demand equation, while the second equation is our postulated adjustment function. The adjustment function states that the actual observed change in utilization is some fraction of the difference between the actual utilization in the previous year and the current desired level of utilization. Substituting the desired demand-for-utilization equation for $Q^{d*}_{it}$ in the adjustment function equation, we obtain the required demand regression equation:

$$Q^d_{it} = \lambda^d_i \; F_i \; (P_{it}, P_{jt}, Z^d_{it}, Z^f_{it}, f_{it}) + (1-\lambda^d_i) \; Q^d_{i,t-1} \qquad (1)$$

Both short- and long-run own-price elasticities of demands for utilization may be estimated from this equation.

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*Marc Nerlove, *Dynamics of Supply: Estimation of Farmers' Response to Price* (Baltimore, Maryland: Johns Hopkins Press, 1958).

*Demand for Ending Stocks*. Ending commercial stocks are the other important outlet for grass seeds. Ending stocks as percentages of total commercial availability vary considerably from year to year, as well as among grass seed types. In 1969, for example, ending stocks as a percentage of commercial availability varied from 18 percent for bentgrass to 30 percent for Merion-Kentucky bluegrass. These stocks of seed are presumably held in expectation of a higher price in the following season. Consequently, following conventional economic theorizing, we hypothesize that the demand for ending stocks is directly related to total commercial availability and inversely related to current price.

More precisely,

$$Q^{es}_{it} = G_i \left(P_{it}, Q^{ca}_{it}, q_{it}\right) \tag{2}$$

where $Q^{es}_i$ = quantity of ending stocks of $i^{\underline{th}}$ seed held by farmers, dealers, and government,

$P_i$ = average price of $i^{\underline{th}}$ grass seed received by farmers,

$Q^{ca}_i$ = total commercial availability (i.e., current production plus beginning stocks) of $\underline{i^{th}}$ grass seed,

$g_{it}$ = disturbance term.

*Supply-Response Function*. Our specification of aggregate Oregon grass seed supply-response functions is quite conventional. This specification embodies three hypotheses often subjected to test by multiple-regression analysis of time-series. Although supply functions can be estimated directly from firm production functions, as well as by budgeting and linear programming techniques, these approaches have been subject to considerable criticism recently.* Moreover, for the present purpose of estimating changes in producers' surpluses, what is often regarded as a weakness of the multiple-regression approach becomes an important strength. Since we wish to estimate the changes in surpluses that would have occurred in the recent past if open field burning regulations had been adopted, it is in fact an advantage that our estimated supply-response functions are based on producers' typical past reactions to changes in relevant variables. (Of course, this advantage becomes a definite disadvantage for research designed to predict future supply changes.)

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*For a very revealing critical analysis of supply functions derived from production functions, see Larry J. Wipf and D. Lee Dawden, *Reliability of Supply Functions Derived from Production Functions,* American Journal of Agricultural Economics, February 1969, pp. 170-79. Wipf and Dawden conclude that supply functions derived from production functions are not empirically relevant when compared with supply functions estimated by regression analysis.

The major hypotheses involved in our specification are as follows. First, we postulate that producers base their production decisions on expected future prices, which, we assume, equal current prices received by farmers. This hypothesis concerning expectations is standard and predicts a positive relationship between quantity-produced and the previous year's price received by farmers. Second, we account for development and diffusion of new technology, introduction of improved fertilizers and pesticides, new cultivation techniques, etc., by including a trend variable in each of our supply-response functions. Once again, we predict a positive sign for the regression coefficient of this variable. Finally, we hypothesize that producers do not adjust their production perfectly each year; we would expect a gradual adjustment to the desired or equilibrium level of production.

The most convenient way of handling the imperfect adjustment phenomenon, as well as obtain the basic supply-response regression equation, is to specify (1) the supply-response function as a desired or equilibrium level of production equation and (2) the adjustment function. Stated formally,

$$Q^{p*}_{it} = H_i (T, P_{i,t-1}, h_{it})$$

where $Q^{p*}_{it}$ = desired, long-run equilibrium quantity of the $i^{\underline{th}}$ grass seed produced in Oregon in year t,

$T$ = time trend,

$P_{i,t-1}$ = $P_{it}$ lagged one year,

$h_{it}$ = disturbance term,

and

$$Q^{p}_{it} - Q^{p}_{i,t-1} = \lambda^{p}_{i} (Q^{p*}_{it} - Q^{p}_{i,t-1})$$

where $0 < \lambda^{p}_{i} < 1$. The adjustment equation indicates that the actual change in production of a particular seed is some fraction of the difference between the actual production in the previous year and the current desired level of production. Substituting the desired-level-of-production supply-response equation for $Q^{p*}_{it}$ in the adjustment function, one obtains the required regression equation

$$Q^{p}_{it} = \lambda^{p}_{i} H_i (T, P_{i,t-1}, h_{it}) + (1 - \lambda^{p}_{i}) Q^{p}_{i,t-1} \tag{3}$$

which enables us to estimate short- and long-run price-elasticities of supply-response. Of course, allowing for such an adjustment function creates special problems because there is likely to be a high sample correlation between $q_{it}$ and $q_{i,t-1}$. This is particularly the case in the grass seed industry where so many seeds are perennials rather than annuals. For this reason, problems of multicollinearity are necessarily associated with the methodology adopted here.

## F. 2 Estimated Demand and Supply-Response Functions

In this section we report time-series, multiple-regression estimates of demand and supply-response functions for six major grass seed crops (ryegrass, tall fescue, red fescue, chewings fescue, Merion-Kentucky bluegrass, and bentgrass) raised in Oregon. No function was estimated for orchardgrass because data on Oregon production unfortunately is available for only 12 years, too few for a meaningful statistical analysis to be performed. The time period of analysis varied among the grass seed crops: 1947-69 for ryegrass, 1956-69 for Merion-Kentucky bluegrass, and 1950-69 for the remaining four crops. Although both additive and multiplicative functional forms were employed to estimate both demand and supply-response functions by ordinary least squares (OLS), the two stage least squares estimation technique (TSLS) was only used in the case of demand functions of the additive type. The results are reported in Tables F. 1 through F. 7.

*Demand for Utilization*. Since ryegrass and tall fescue are principally used as livestock forage grasses, the number of cattle in the twelve southern U.S. states and three foreign countries (Canada, West Germany, and France) became our domestic and foreign demand-shift variables, respectively. For the other four grasses which are chiefly used for turf, new housing starts were hypothesized to be responsible for major shifts in demand. Not all of these specified exogenous variables appear in the estimated equations reported in Tables F. 1 - F.6, however. In our early regression runs we discovered that the number of cattle in the three foreign countries was strongly correlated with its domestic equivalent; the foreign demand-shifter was deleted after we found that recasting the data in logarithmic first differences did not eliminate the problem of multicollinearity. Certain other exogenous variables were also deleted from some equations. In each instance, the regression coefficient was not statistically significantly different from zero, or we again confronted the problem of multicollinearity.

Nonetheless, with the exception of tall fescue, the model performed reasonably well, and the results were consistent with our theoretical expectations. For most seeds, TSLS performed rather better than OLS when judged by conventional statistical tests. However, in the case of red fescue (see Table F.3), TSLS increased the statistical significance of the own-price and price-of-substitute regression coefficients but resulted in a clearly unrealistic short-run own-price elasticity of demand. Consequently, a priori reasoning and knowledge of the price-elasticities for other seeds suggested that the TSLS red fescue regression coefficients were unreliable.

Typically the coefficients of adjustment (i.e., the regression coefficient of the lagged dependent variable) had its theoretically anticipated sign and were statistically significant at the 10 percent level or better. It should be noted, however, that specification changes not only affected the statistical significance of the adjustment coefficient but also its sign. In the case of ryegrass (see Table F.1), experimentation by deletion was undertaken because of the multicollinearity that existed between the lagged dependent variable and the demand shifter; the results reported in Table F. 1 only indicate the deletion of the shift variable. In contrast, the demand shifters were not statistically significant for red and chewings fescues (see Tables F.3 and F.4).

Table F.1. Estimated Demand Relationships for Ryegrass, 1947-69

| Form and method of estimation | Regression Coefficients for | | | | | Inter-ceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasti-city | Long-run price Elasti-city | Durbin Watson Statis tic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Z_t^d$ | $P_{it}$ | $P_{jt}$ | $Q_{t-1}^d$ | $Q_t^{ca}$ | | | | | | | |
| Demand for Utilization | | | | | | | | | | | | |
| O.L.S. | $8.7482^a$<br>(5.226) | $-11.5535^a$<br>(5.504) | 0.6154<br>(0.929) | -0.0461<br>(0.289) | | -49.4281<br>(1.538) | .9311 | 60.8040 | 18 | -0.6412 | | 2.0938* |
| O.L.S. | | $-6.6883^b$<br>(2.302) | -0.2035<br>(0.205) | $0.7027^a$<br>(6.508) | | 88.4874<br>(3.124) | .8265 | 30.1762 | 19 | -0.3712 | -1.2486 | 2.6513** |
| L.L.S | $1.9732^a$<br>(4.088) | $-0.6132^a$<br>(4.464) | 0.0558<br>(0.784) | 0.1386<br>(0.890) | | -0.6408<br>(1.471) | .9285 | 58.4714 | 18 | -0.6132 | -0.7119 | 1.9483* |
| L.L.S. | | $-0.3830^b$<br>(2.262) | -0.1369<br>(0.147) | $0.7129^a$<br>(7.849) | | 0.9395<br>(3.462) | .8622 | 39.7400 | 19 | -0.3830 | -1.3341 | 2.5450** |
| TSLS | $10.8006^a$<br>(10.575) | $-17.3563^a$<br>(11.290) | $1.2263^a$<br>(3.108) | $-0.3155^a$<br>(3.096) | | -43.4817<br>(2.345) | .9771 | 192.1912 | 18 | -0.9633 | | 2.7137** |
| TSLS | | $-20.3675^a$<br>(9.197) | $1.0253^b$<br>(2.090) | $0.4277^a$<br>(6.834) | | 200.8887<br>(10.230) | .9593 | 149.3020 | 19 | -1.1304 | -1.9752 | 2.1193* |
| Demand for Ending Stocks | | | | | | | | | | | | |
| O.L.S. | | $-3.0136^c$<br>(1.833) | | | $0.2142^a$<br>(4.419) | 22.1242<br>(1.246) | .7883 | 37.2448 | 20 | -0.5810 | | 2.1340* |
| L.L.S. | | $-0.6484^c$<br>(1.977) | | | $1.1317^a$<br>(6.083) | -0.4438<br>(0.713) | .8488 | 56.2071 | 20 | -0.6484 | | 2.4458* |
| TSLS | | $-5.8808^d$<br>(1.427) | | | 0.1524<br>(1.125) | 51.5389<br>(1.063) | .7708 | 33.6249 | 20 | -1.1326 | | 1.6872* |

Note: Figures in parentheses are t-statistic.

$P_{jt}$ = Average price per 100 lbs of timothy seed received by farmers.

a, b, c, and d indicate significance at the 1, 5, 10, and 20 percent levels, respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson Statistic is inconclusive.

Table F.2. Estimated Demand Relationships for Tall Fescue, 1950-69

| Form and method of estimation | Regression Coefficients for | | | | | Inter-ceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasti-city | Long-run price Elasti-city | Durbin Watson Statis-tic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Z_{tt}^d$ | $P_{it}$ | $P_{jt}$ | $Q_{t-1}^d$ | $Q_t^{ca}$ | | | | | | | |
| Demand for Utilization | | | | | | | | | | | | |
| O.L.S. | 2.9439$^b$<br>(2.392) | -0.0562<br>(0.308) | -0.7393$^d$<br>(1.738) | 0.2913<br>(1.169) | | -44.3839<br>(1.589) | .8337 | 17.5418 | 14 | -0.0204 | -0.0288 | 2.2236* |
| O.L.S. | 2.3215$^c$<br>(1.851) | -0.0904<br>(0.468) | | 0.3969$^d$<br>(1.542) | | -42.4295<br>(1.428) | .7978 | 19.7247 | 15 | -0.0328 | -0.0544 | 1.8776* |
| L.L.S. | 2.5472$^d$<br>(3.003) | -0.1008<br>(0.922) | -0.2655$^d$<br>(1.437) | 0.0865<br>(0.345) | | -1.8565<br>(2.057) | .8333 | 17.3636 | 14 | -0.1008 | -0.1103 | 2.1397* |
| L.L.S. | 2.2049$^b$<br>(2.617) | -0.1488$^d$<br>(1.382) | | 0.1316<br>(0.511 | | -1.6973<br>(1.831) | .8087 | 21.1154 | 15 | -0.1488 | -0.1713 | 1.6632* |
| TSLS | 0.5938<br>(0.612) | -3.2594$^d$<br>(4.358) | 0.0691<br>(0.206) | -0.2746<br>(1.316) | | 80.6821<br>(2.365) | .9289 | 45.7543 | 14 | -1.1796 | | 2.3766** |
| TSLS | 0.6961<br>(0.863) | -3.1723$^a$<br>(5.309) | | -0.2665$^d$<br>(1.344) | | 77.2443<br>(2.681) | .9287 | 66.5882 | 15 | -1.1500 | | 2.4518** |
| Demand for Ending Stocks | | | | | | | | | | | | |
| O.L.S. | | 0.0939<br>(0.530) | | | 0.3049$^a$<br>(3.212) | -5.1804<br>(0.761) | .4173 | 5.7294 | 16 | 0.1119 | | 1.0694** |
| L.L.S. | | 0.2122<br>(0.599) | | | 0.1858$^a$<br>(4.071) | -2.4111<br>(2.284) | .5679 | 10.5063 | 16 | 0.2122 | | 1.4255* |
| TSLS | | 2.4258$^a$<br>(4.671) | | | 0.8866$^a$<br>(6.297) | -70.5516<br>(4.742) | .7492 | 23.8948 | 16 | 2.8918 | | 2.1447* |

Note: Figures in parentheses are t-statistic.

$P_{jt}$ = Average price per 100 lbs of orchardgrass received by farmers.

a, b, c, and d indicate significance at the 1, 5, 10, and 20 percent levels respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson Statistic is inconclusive.

Table F.3. Estimated Demand Relationships for Red Fescue, 1950-69

| Form and method of estimation | Regression Coefficients for | | | | | Inter-ceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasti-city | Long-run price Elasti-city | Durbin Watson Statis-tic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Z_t^d$ | $P_{it}$ | $P_{jt}$ | $Q_{t-1}^d$ | $Q_t^{ca}$ | | | | | | | |
| Demand for Utilization | | | | | | | | | | | | |
| O.L.S. | 2.6589<br>(0.447) | $-0.3844^d$<br>(1.508) | $-0.3562^d$<br>(1.385) | $0.6757^a$<br>(3.772) | | 3.3987<br>(0.330) | .7471 | 10.3372 | 14 | -0.7605 | -2.3450 | 1.9487* |
| O.L.S. | | $-0.3882^d$<br>(1.565) | $0.3603^d$<br>(1.441) | $0.6609^a$<br>(3.859) | | 7.4485<br>(1.564) | .7435 | 14.4897 | 15 | -0.7680 | -2.3682 | 2.0162* |
| L.L.S. | | $-0.6841^d$<br>(1.447) | $0.7274^d$<br>(1.544) | $0.7187^a$<br>(6.828) | | 0.3153<br>(0.985) | .8662 | 32.1746 | 15 | -0.6841 | -2.4319 | 2.6670** |
| TSLS | -0.6039<br>(0.417) | $-4.5764^a$<br>(16.332) | $4.3649^a$<br>(16.245) | -0.0210<br>(0.321) | | 31.3637<br>10.1866) | .9853 | 235.1980 | 14 | -9.0539 | | 1.1581** |
| TSLS | 2.9499<br>(0.478) | -0.0365<br>(0.412) | | $0.6982^a$<br>(3.660) | | 22.7394<br>(0.211) | .7089 | 12.1779 | 15 | -0.0722 | -0.2392 | 2.0914* |
| Demand for Ending Stocks | | | | | | | | | | | | |
| O.L.S. | | $-0.0839^c$<br>(1.697) | | | $0.1540^d$<br>(1.356) | 4.8231<br>(1.462) | .4391 | 6.2624 | 16 | -0.5298 | | 1.8962* |
| L.L.S. | | $-0.5239^d$<br>(1.396) | | | $0.7525^b$<br>(2.094) | 0.4586<br>(0.515) | .4970 | 7.9094 | 16 | -0.5239 | | 2.1462* |
| TSLS | | -0.0680<br>(1.281) | | | $0.1769^d$<br>(1.483) | 3.9104<br>(1.114) | .3997 | 5.3239 | 16 | -0.4294 | | 1.7345* |

Note: Figures in parentheses are t-statistic.

$P_{jt}$ = Average price per 100 lbs of chewings fescue received by farmers.

a, b, c, and d indicate significance at the 1, 5, 10, and 20 percent levels, respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson statistic is inclusive.

Table E.4. Estimated Demand Relationships for Chewings Fescue, 1950-69

| Form and method of estimation | Regression Coefficients for | | | | | Inter-ceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasti-city | Long-run price Elasti-city | Durbin Watson Statis-tic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Z_t^d$ | $P_{it}$ | $P_{jt}$ | $Q_{t-1}^d$ | $Q_t^{ca}$ | | | | | | | |
| Demand for Utilization | | | | | | | | | | | | |
| O.L.S. | 1.2321<br>(0.536) | $-0.2434^b$<br>(2.237) | $0.1436^d$<br>(1.422) | $0.3268^b$<br>(2.145) | | 5.5782<br>(1.627) | .7390 | 9.9084 | 14 | -1.0572 | -1.5704 | 2.9279** |
| O.L.S. | | $-0.2398^b$<br>(2.262) | $0.1430^d$<br>(1.451) | $0.3332^b$<br>(2.248) | | 7.2219<br>(4.846) | .7336 | 13.7698 | 15 | -1.0415 | -1.5620 | 2.9433** |
| L.L.S. | 0.1708<br>(0.274) | $-0.9567^d$<br>(1.433) | 0.4614<br>(0.719 | $0.4404^b$<br>(2.793) | | 1.1303<br>(3.628) | .7363 | 9.7570 | 14 | -0.9567 | -1.7096 | 2.7118** |
| L.L.S. | | $-0.9627^d$<br>(1.489) | 0.4760<br>(0.769) | $0.4403^b$<br>(2.833) | | 1.1443<br>(3.844) | .7349 | 13.8900 | 15 | -0.9627 | -1.7200 | 2.7223** |
| TSLS | 1.7758<br>(0.850) | $-0.6603^a$<br>(3.061) | $0.5195^b$<br>(2.655) | 0.1073<br>(0.629) | | 6.8090<br>(2.167) | .7878 | 12.9913 | 14 | -2.8679 | -3.2126 | 2.4142** |
| TSLS | | $-0.6356^a$<br>(3.002) | $0.5010^b$<br>(2.601) | 0.1267<br>(0.756) | | 9.0863<br>(5.583) | .7768 | 17.4031 | 15 | -2.7606 | -3.1611 | 2.4749* |
| Demand for Ending Stocks | | | | | | | | | | | | |
| O.L.S. | | 0.0156<br>(0.377) | | | $0.4985^a$<br>(3.012) | -2.1670<br>(0.769) | .6256 | 13.3698 | 16 | 0.1367 | | 1.3352** |
| L.L.S. | | -0.3499<br>(0.916) | | | $0.7928^c$<br>(2.015) | 0.1935<br>(0.215) | .6360 | 13.9875 | 16 | -0.3499 | | 1.2359** |
| TSLS | | -0.0010<br>(0.022) | | | $0.4418^b$<br>(2.532) | -1.0972<br>(0.365) | .6223 | 13.1818 | 16 | -0.0087 | | 1.2782** |

Note: Figures in parentheses are t-statistic.

$P_{jt}$ = Average price per 100 lbs of red fescue received by farmers.

a, b, c, and d indicate significance at the 1, 5, 10, and 20 percent levels, respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson statistic is inconclusive.

Table F.5. Estimated Demand Relationships for Merion-Kentucky Bluegrass, 1956-69

| Form and method of estimation | Regression Coefficients for | | | | | Inter-ceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasti-city | Long-run price Elasti-city | Durbin Watson Statis-tic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Z_t^d$ | $P_{it}$ | $P_{jt}$ | $Q_{t-1}^d$ | $Q_t^{ca}$ | | | | | | | |
| Demand for Utilization | | | | | | | | | | | | |
| O.L.S. | $2.4989^c$<br>(2.070) | $-0.0335^a$<br>(4.502) | $0.0390^d$<br>(1.656) | $0.2652^c$<br>(1.915) | | 0.9127<br>(0.628) | .8870 | 17.6527 | 9 | -0.8523 | -1.1600 | 2.0916* |
| O.L.S. | $3.5403^b$<br>(2.919) | $-0.0424^a$<br>(6.475) | $0.0507^c$<br>(1.981) | | | 0.7409<br>(0.454) | .8410 | 17.6040 | 10 | -1.0788 | -1.1360 | 1.4788** |
| L.L.S. | 0.8754<br>(1.231) | $-0.6799^b$<br>(2.288) | 0.1678<br>(0.722) | $0.3312^c$<br>(2.198) | | 1.2831<br>(3.351) | .8118 | 9.7039 | 9 | -0.6797 | -1.0163 | 2.8123** |
| TSLS | $3.0925^b$<br>(3.038) | $-0.0449^a$<br>(5.880) | $0.0622^b$<br>(2.898) | 0.1333<br>(1.063) | | 0.8712<br>(0.731) | .9241 | 27.4052 | 9 | -1.1424 | -1.3181 | 2.9287** |
| Demand for Ending Stocks | | | | | | | | | | | | |
| O.L.S. | | -0.0251<br>(0.361) | | | $0.4456^a$<br>(4.489) | -0.2839<br>(0.264) | .8755 | 38.68 | 11 | -1.1875 | | 2.3606* |
| L.L.S. | | -0.0519<br>(0.155) | | | $1.2680^a$<br>(4.404) | -0.5782<br>(0.717) | .8456 | 49.5247 | 11 | -0.0519 | | 2.6865** |
| TSLS | | $-0.0138^d$<br>(4.692) | | | $0.3110^b$<br>(2.857) | 1.3887<br>(1.121) | .9001 | | 11 | -0.6529 | | 2.5407* |

Note: Figures in parentheses are t-statistic

$P_{jt}$ = Average price per 100 lbs of chewings fescue received by farmers.

a, b, c, and d indicate significance at the 1, 5, 10, and 20 percent levels, respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson statistic is inconclusive.

Table F.6. Estimated Demand Relationships for Bentgrass, 1950-69

| Form and method of estimation | Regression Coefficients for $Z_t^d$ | $P_{it}$ | $P_{jt}$ | $Q_{t-1}^d$ | $Q_t^{ca}$ | Interceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasticity | Long-run price Elasticity | Durbin Watson Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Demand for Utilization | | | | | | | | | | | | |
| O.L.S. | 1.1803<br>(0.549) | $-0.0689^b$<br>(2.433) | 0.0191<br>(0.758) | $0.5523^a$<br>(3.826) | | 3.2961<br>(1.065) | .8196 | 15.8996 | 14 | -0.4675 | -1.0513 | 2.0241* |
| O.L.S. | | $-0.0621^b$<br>(2.497) | 0.0168<br>(0.690) | $0.5589^a$<br>(3.978) | | 4.7539<br>(3.060) | .8157 | 22.1292 | 15 | -0.4213 | -0/9551 | 2.0050* |
| L.L.S. | 0.3131<br>(0.629) | $-0.3692^b$<br>(2.099) | 0.0094<br>(0.085) | $0.6663^a$<br>(5.689) | | 0.7836<br>(2.313) | .8943 | 29.6800 | 14 | -0.3692 | -1.1064 | 1.7170* |
| L.L.S. | 0.3134<br>(0.651) | $-0.3669^b$<br>(2.183) | | $0.6633^a$<br>(6.141) | | 0.7957<br>(2.679) | .8944 | 41.0833 | 15 | -0.3669 | -1.0865 | 1.6841** |
| TSLS | $5.1896^a$<br>(4.068) | $-0.1899^a$<br>(7.850) | $0.0774^a$<br>(4.852) | $0.2283^b$<br>(2.525) | | 2.5263<br>(1.586) | .9525 | 70.1454 | 14 | -1.2884 | 01.6696 | 2.3020* |
| Demand for Ending Stocks | | | | | | | | | | | | |
| O.L.S. | | 0.0141<br>(0.896) | | | $0.3266^a$<br>(3.779) | -1.0101<br>(.793) | .6105 | 12.5301 | 16 | 0.0274 | | 0.9281** |
| L.L.S. | | 0.2759<br>(0.917) | | | $1.0658^a$<br>(4.021) | -1.0683<br>(1.586) | .6394 | 13.5819 | 16 | 0.5356 | | 1.0284** |
| TSLS | | $0.0418^a$<br>(3.965) | | | $0.4451^c$<br>(1.785) | -3.0931<br>(1.704) | .6587 | 14.2166 | 16 | 0.0811 | | 0.8482** |

Note: Figures in parentheses are t-statistic.

$P_{jt}$ = Average price per 100 lbs of chewings fescue received by farmers.

a, b, and c, indicate significance at the 1, 5, and 10 percent levels, respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson statistic is inconclusive.

Table F.7. Estimated Supply Response Relations for Selected Grass Seed Crops

| Type of grass seed | Form and method of estimation | Regression Coefficients for | | | Inter-ceptor | $R^2$ | F-Statistic | Degrees of Freedom | Short-run price Elasti-city | Long-run price Elasti-city | Durbin Watson Statis-tic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T | $P_{i,t-1}$ | $Q_{i,t-1}$ | | | | | | | |
| Ryegrass | O.L.S. | 4.3355$^a$<br>(3.310) | 9.4672$^b$<br>(2.563) | 0.4455$^b$<br>(2.091) | 245.3570 | .7890 | 41.6731 | 19 | 0.5245 | 0.9459 | 2.0758* |
| | L.L.S. | 1.9667$^a$<br>(2.976) | 0.7028$^a$<br>(3.424) | 0.6148$^a$<br>(3.351) | -3.2355 | .8494 | 11.2305 | 19 | 0.7028 | 1.8245 | 1.9004* |
| Tall Fescue | O.L.S. | 0.3234$^a$<br>(4.655) | 0.1693$^a$<br>(4.557) | 0.6233$^a$<br>(5.635) | -19.4357 | .8930 | 41.7161 | 15 | 0.4079 | 1.0828 | 2.1602* |
| | L.L.S. | 3.0576$^a$<br>(3.988) | 0.6092$^a$<br>(4.002) | 0.6582$^a$<br>(5.548) | -5.8607 | .8462 | 27.4995 | 15 | 0.6092 | 1.7823 | 2.6909** |
| Red Fescue | O.L.S. | | 0.0242<br>(0.962) | 0.8954$^a$<br>(5.476) | -0.0511<br>(0.038) | .7045 | 19.0690 | 16 | 0.1774 | 1.6960 | 2.6978** |
| | L.L.S. | | 0.3075<br>(1.237) | 0.8365$^a$<br>(5.071) | -0.3180<br>(0.745) | .6695 | 17.6584 | 16 | 0.3075 | 1.8807 | 2.8287** |
| Chewings Fescue | O.L.S. | 0.0528<br>(0.580) | -0.0180<br>(0.310) | 0.2683<br>(0.801) | 2.4719<br>(0.344) | .2361 | 1.6487 | 16 | -0.0744 | | 2.4002* |
| | L.L.S. | 1.0001<br>(1.087) | 0.0233<br>(1.049) | 0.3442<br>(0.084) | -1.2720<br>(0.722) | .3047 | 2.3367 | 16 | 0.0233 | 0.0355 | 2.4961* |
| Merion-Kentucky Bluegrass | O.L.S. | 0.0361<br>(0.312) | 0.0059<br>(0.544) | 0.6438<br>(0.725) | -2.2675 | .3710 | 1.9662 | 10 | 0.3787 | 1.0632 | 2.0674* |
| | L.L.S. | 2.1467<br>(1.143) | 0.6317$^b$<br>(2.180) | 0.6902$^b$<br>(2.239) | -5.0107 | .5339 | 3.8178 | 10 | 0.6317 | 2.0390 | 2.3250* |
| Bentgrass | O.L.S. | | 0.0188<br>(0.738) | 0.8092$^a$<br>(4.449) | 0.6093<br>(0.312) | .6583 | 15.4133 | 16 | 0.1265 | 0.6630 | 2.3454* |
| | L.L.S. | | 0.2364$^d$<br>(1.567) | 0.8460$^a$<br>(7.110) | -0.2307<br>(0.754) | .8200 | 36.4598 | 16 | 0.2364 | 1.5351 | 2.5363** |

Note: Figures in parentheses are t-statistic.

a, b, and d indicate significance at the 1, 5, and 20 percent levels, respectively.

*Reject the hypothesis that auto-correlation is present at the 95 percent confidence level.

**The Durbin-Watson statistic is inconclusive.

*Demand for Ending Stocks*. Although our empirical results for ending-stock demands are less robust than those obtained for utilization demands (compare lower and upper halves of Tables F.1-F.6), none of our major hypotheses were generally rejected. Theoretical considerations suggested that, other things equal, demands for ending stocks would vary directly with total commercial availability (current production plus beginning stocks) and inversely with current price.

For all grasses, the regression coefficients for total commercial availability have their expected positive signs and are significantly different from zero at the 20 or better percent level. In contrast, however, only four grass seeds (ryegrass, red fescue, chewings fescue, and Merion-Kentucky bluegrass) had own-price regression coefficients with the anticipated negative signs. Tall fescue and bentgrass both had unexpected positively-signed own-price regression coefficients, but these coefficients are statistically insignificant except when estimated by TSLS. Unfortunately, a diligent search did not reveal the cause(s) of these peculiar findings for tall fescue and bentgrass.

For the grasses with negatively-signed own-price regression coefficients, estimated own-price elasticities of demand for ending stocks varied from -0.52 to -1.13.* Our best estimates for individual grasses are as follows:

| | |
|---|---|
| Ryegrass | -0.65 |
| Red Fescue | -0.53 |
| Chewings Fescue | -0.35 |
| Merion-Kentucky Bluegrass | -0.65 |

*Estimated Supply-Response Functions*. Table F.7 reports our estimated supply-response relationships for the six grass seed types under investigation here. With the exception of chewing fescue, the model performed reasonably well when evaluated by the usual statistical tests, and both OLS and LLS regression estimates are rather similar. In the case of chewings fescue, five of six estimated regression coefficients have their theoretically expected signs, but none are statistically significantly different from zero. For the other five grasses, however, all but two estimated regression coefficients have their expected positive signs and are statistically significant at the 5 percent level: only the trend regression coefficient for Merion-Kentucky bluegrass and the coefficient-of-adjustment regression coefficient for bentgrass are not statistically significant.** Thus, none of our basic hypotheses concerning grass seed producers supply-response can be rejected on the basis of results reported in Table F.7.

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*This range of elasticity estimates does not include estimates derived from statistically insignificant regression coefficients.

**Problems of multicollinearity required the deletion of the trend variable from the estimated functions for red fescue and bentgrass.

Prices of several substitute seeds were included in our initial regression experiments for each of the six grass seeds. Here, however, we present regression results only for those substitute seed prices which provided the best statistical results. As Table F.2 indicates, in the case of tall fescue, all substitute seed prices proved to have the theoretically unexpected sign or to be statistically insignificant. In contrast, the regression coefficients for substitute seed prices did have the expected sign and were statistically significant at a probability level of at least 20 percent for the other five seeds.

With the single exception of tall fescue, estimated own-price regression coefficients have their theoretically anticipated sign and are statistically significant at the 20 or better percent level. Although our tall fescue results are disappointing, they are relatively easy to explain. Tall fescue is an important export crop, but unfortunately there is no data on exports prior to 1966. Therefore, the inclusion of exports in data measuring utilization may be the reason for the insignificant own-price regression coefficients when estimated by OLS and LLS. Interestingly, estimation of the tall fescue demand function by TSLS did result in a statistically significant own-price regression coefficient, but this strong result is negated by the theoretically unexpected sign for the coefficient of adjustment.

As one would expect, estimated short- and long-run own-price elasticities of demand vary with the assumed functional form, estimation method, and among grass seed types. When estimated at the mean, short-run elasticities range from -0.37 to -2.87, and long-run elasticities vary from -0.71 to -3.21.* However, with the exception of the TSLS estimations of chewings fescue demand reported in Table F.4, our estimated short- and long-run own-price elasticities of demand for grass seeds are less than -1.30 and -2.50, respectively.

Our best estimate of the long-run own-price elasticities of demand for each seed crop are as follows:

| | |
|---|---|
| Ryegrass | -1.98 |
| Red Fescue | -2.37 |
| Chewings Fescue | -1.57 |
| Merion-Kentucky Bluegrass | -1.32 |
| Bentgrass | -1.67 |

Unfortunately, as indicated previously, we were unable to estimate a satisfactory demand function for tall fescue.

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*The range of elasticity estimates reported in the text does not encompass own-price elasticity estimates derived from statistically insignificant regression coefficients.

Excluding estimates based on statistically insignificant regression coefficients, our estimated short-run price-elasticities range from 0.24 for bentgrass to 0.70 for ryegrass. Our best estimates of long-run price elasticities are as follows:

| | |
|---|---|
| Ryegrass | 1.82 |
| Tall Fescue | 1.78 |
| Red Fescue | 1.88 |
| Merion-Kentucky Bluegrass | 2.04 |
| Bentgrass | 1.54 |

These rather low long-run price-elasticity estimates are consistent with independent evidence that alternative crops or land uses to grass seed production in the Willamette Valley are limited.*

## F.3. Calculated Demand and Supply Functions

Tables F.8 and F.9 present the linear demand and supply functions which underlie our computations of the changes in output, price, consumers' surplus, and rents associated with alternative field burning control policies. Each equation is calculated to satisfy two conditions. Each generates a linear demand or supply curve that (1) passes through the 1965-69 average observed prices and quantities with (2) a price-elasticity at that point equal to the best multiple-regression based elasticity estimate for that seed type reported earlier in this appendix. The first seven columns of Tables F.8 and F.9 present the price, quantity and price-elasticity data used to calculate all but one of the desired equations. Since we did not estimate non-Oregon supply functions, we required that function to have a constant term equal to Fisher's estimate of average variable costs for high-cost Willamette Valley producers.**

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*For evidence concerning the limited alternatives available to farmers now raising grass seeds, see Frank S. Conklin and R. Carlyle Bradshaw, *Farmer Alternatives to Open Field Burning: An Economic Appraisal*, Special Report 336, Agricultural Experiment Station, Oregon State University, Corvallis, October 1971, especially pp. 4-8 and 14.

**The constant terms for the non-Oregon supply functions in Table F.9 were obtained from sample data reported in Douglas E. Fisher, *An Economic Analysis of Farms Producing Grass Seed in the Willamette Valley, with Special Attention to the Cultural Practice of Field Burning*, unpublished Ph.D. dissertation, Oregon State University, June 1972.

Table F.8. Linear Demand Functions for the 1965-69 Period, by Seed Type

| Seed Type | Average Prices and Quantites, 1965-69 | | | | Own-Price-Elasticities | | | Demand Function Equations | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantities-Demanded | | | | | | | | |
| | Prices (per 100 lbs) | Aggregate (million lbs) | Utilization (million lbs) | Ending Stocks (million lbs) | Aggregate | Utilization | Ending Stocks | Aggregate | Utilization | Ending Stocks |
| Ryegrass | 6.86 | 164.289 | 158.585 | 5.704 | -1.94 | -1.98 | -0.65 | P= 10.4074-0.0216Q | P= 10.3247-0.0216Q | P=17.4140-0.2706Q |
| Tall fescue | 12.08 | 74.743 | 60.040 | 14.703 | -1.49 | -1.85 | 0 | P= 20.2085-0.1088Q | P= 18.6098-0.1088Q | $Q^{es}=14.703$ |
| Red fescue | 26.50 | 26.164 | 20.094 | 6.070 | -1.94 | -2.37 | -0.53 | P= 40.1375-0.5212Q | P= 37.6812-0.5565Q | P=76.5000-8.2372Q |
| Chewings fescue | 26.70 | 11.760 | 9.235 | 2.525 | -1.53 | -1.57 | -0.35 | P= 48.3591-1.8416Q | P= 43.7090-1.8416Q | $Q^{es}=2.525$ |
| Merion-Kentucky Bluegrass | 68.90 | 7.262 | 4.512 | 2.750 | -1.07 | -1.32 | -0.65 | P=133.4991-8.8968Q | P=121.1551-5741Q | P=175.1931-38.6100Q |
| Bentgrass | 37.70 | 9.962 | 7.444 | 2.518 | -1.25 | -1.67 | 0 | P= 67.9208-3.0331Q | P= 60.25113-3.0331Q | $Q^{es}=2.518$ |

Note: Functions are caluclated according to procedure described in text.

Table F.9. Linear Supply Functions for the 1965-69 Period, by Seed Type

| | Average Prices and Quantities, 1965-69 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantities-Supplied | | | Price-Elasticities | | | Supply Function Equations | | |
| Seed Type | Prices (per 100 lbs) | Aggregate (million lbs) | Oregon (million lbs) | Non-Oregon (million lbs) | Aggre-gate | Oregon | Non-Oregon | Aggregate | Oregon | Non-Oregon |
| Ryegrass | 6.86 | 164.289 | 158.585 | | 1.73 | 1.82 | | $P= 2.9044+0.0241Q$ | $P= 3.0908+.0238Q$ | |
| Tall fescue | 12.08 | 74.743 | 10.248 | 49.793 | 1.48 | 1.78 | 1.86 | $P= 3.9195+0.1091Q$ | $P= 5.2933+0.6622Q$ | $P= 5.5700+0.1307Q$ |
| Red fescue | 26.50 | 26.164 | 6.724 | 13.370 | 1.10 | 1.88 | 1.45 | $P= 2.4316+0.9200Q$ | $P=12.4048+2.0964Q$ | $P= 8.2202+1.3672Q$ |
| Chewings fescue | 26.70 | 11.760 | 6.800 | 2.435 | 1.35 | 1.75 | 1.44 | $P= 6.9446+1.6798Q$ | $P=12.0302+2.1575Q$ | $P= 8.2178+7.5873Q$ |
| M K blue grass | 68.90 | 7.262 | 1.760 | 2.752 | 0.70 | 2.04 | 1.18 | $P=-30.1719+13.6426Q$ | $P=35.1324+19.1939Q$ | $P=10.5202+21.2314Q$ |
| Bentgrass | 37.70 | 9.962 | 7.048 | 0.396 | 1.15 | 1.54 | 1.63 | $P= 5.0367+3.2787Q$ | $P=13.2195+3.4734Q$ | $P=14.5205+58.4795Q$ |

Note: Functions are calculated according to procedure described in text.

# APPENDIX G

Table G.1. Estimated Consumers' Surplus, Oregon and Non Oregon Rents for Ryegrass in Supply Situation I Without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

| | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ban on Burning | | | Once in Three Years Burning | | | Alternate Year Burning | | |
| | | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Price per 100 lbs. | 6.86 | 7.0568 | 7.2132 | 7.36971 | 6.9915 | 7.0959 | 7.2002 | 6.9589 | 7.0372 | 7.1154 |
| Average variable cost per 100 lbs. | 2.68000 | 3.09390 | 3.42494 | 3.74604 | 2.9595 | 3.1766 | 3.3974 | 2.8870 | 3.0525 | 3.2180 |
| Aggregate Output (100 lbs) | 1,643,890 | 1,551,225 | 1,478,788 | 1,406,337 | 1,581,416 | 1,533,125 | 1,484,823 | 1,596,510 | 1,560,291 | 1,524,066 |
| Oregon Output (100 lbs) | 1,585,850 | 1,494,987 | 1,421,511 | 1,348,068 | 1,525,610 | 1,476,629 | 1,427,635 | 1,540,918 | 1,504,184 | 1,467,479 |
| Non-Oregon Output (100 lbs) | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| Consumers' Surplus | 2,913,994 | 2,598,767 | 2,361,765 | 2,136,008 | 2,700,948 | 2,538,510 | 2,381,077 | 2,752,758 | 2,629,270 | 2,508,605 |
| Change in Consumers' Surplus | | 315,227 | 552,229 | 777,986 | 213,046 | 375,484 | 532,917 | 161,236 | 284,724 | 405,389 |
| Percentage Change | | 10.82 | 18.95 | 26.70 | 7.31 | 12.89 | 18.29 | 5.53 | 9.77 | 13.91 |
| Oregon Rents | 6,628,853 | 5,924,484 | 5,384,996 | 4,871,473 | 6,151,271 | 5,787,249 | 5,429,039 | 6,274,587 | 5,993,722 | 5,719,338 |
| Change in Oregon Rents | | 704,369 | 1,243,857 | 1,757,380 | 477,578 | 841,604 | 1,199,814 | 354,266 | 635,131 | 909,515 |
| Percentage Change | | 10.63 | 18.76 | 26.51 | 7.20 | 12.70 | 18.10 | 5.34 | 9.58 | 13.72 |
| Non-Oregon Rents | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| Change in Non-Oregon Rents | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| Percentage Change | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| Sum of Surplus and Rents | 9,542,847 | 8,523,251 | 7,746,761 | 7,007,481 | 8,852,219 | 8,325,759 | 7,810,116 | 9,027,345 | 8,622,992 | 8,227,943 |
| Change in Sum | | 1,019,558 | 1,796,086 | 2,535,366 | 690,628 | 1,217,088 | 1,732,731 | 515,502 | 919,855 | 1,514,904 |
| Percentage Change | | 10.68 | 18.82 | 26.57 | 7.24 | 12.75 | 18.16 | 5.40 | 9.64 | 15.87 |

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[a] See Part III, sections A and B for a discussion of definitions and computation methods.

Table C.2. Estimated Consumers' Surplus, Oregon and Non-Oregon Rents for Tall Fescue in Supply Situation I Without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

|  | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Ban on Burning |  |  | Once in Three Years Burning |  |  | Alternate Year Burning |  |  |
|  |  | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Price per 100 lbs. | 12.08 | 12.3703 | 12.60639 | 12.84247 | 12.2719 | 12.4239 | 12.5867 | 12.2228 | 12.3408 | 12.4588 |
| Average variable cost per 100 lbs. | 4.66780 | 5.25880 | 5.73162 | 6.20444 | 5.0618 | 5.3770 | 5.6922 | 4.9633 | 5.1997 | 5.4361 |
| Agregate Output (100 lbs) | 747,430 | 720,422 | 698,723 | 677,024 | 729,463 | 714,997 | 700,531 | 733,983 | 723,134 | 712,285 |
| Oregon Output (100 lbs) | 102,480 | 97,946 | 94,371 | 90,796 | 99,437 | 97,053 | 94,669 | 100,181 | 98,393 | 96,606 |
| Non-Oregon Output (100 lbs) | 497,930 | 520,298 | 538,362 | 556,425 | 512,773 | 524,814 | 536,857 | 509,009 | 518,041 | 527,073 |
| Consumers' Surplus | 3,037,742 | 2,823,406 | 2,655,855 | 2,493,490 | 2,894,713 | 2,781,045 | 2,669,647 | 2,930,702 | 2,844,701 | 2,759,998 |
| Change in Consumers' Surplus |  | 214,336 | 381,887 | 544,252 | 143,029 | 256,700 | 368,095 | 107,040 | 193,041 | 277,244 |
| Percentage Change |  | 7.06 | 12.57 | 17.92 | 4.71 | 8.45 | 12.12 | 3.52 | 6.35 | 9.14 |
| Oregon Rents | 759,602 | 696,543 | 648,779 | 602,707 | 716,955 | 684,448 | 652,695 | 727,259 | 702,633 | 678,437 |
| Change in Oregon Rents |  | 63,059 | 110,823 | 156,895 | 42,647 | 75,158 | 106,907 | 32,343 | 56,969 | 81,165 |
| Percentage Change |  | 8.30 | 14.59 | 20.65 | 5.62 | 9.90 | 14.08 | 4.26 | 7.50 | 10.69 |
| Non-Oregon Rents | 1,620,762 | 1,769,091 | 1,894,063 | 2.023,292 | 1,718,287 | 1,799,934 | 1,883,488 | 1,693,155 | 1,753,766 | 1,815,461 |
| Change in Non-Oregon Rents |  | 148,336 | 273,301 | 402,530 | 97,525 | 179,172 | 262,726 | 72,393 | 133,004 | 194,699 |
| Percentage Change |  | 9.15 | 16.86 | 24.84 | 6.02 | 11.15 | 16.21 | 4.47 | 8.21 | 12.01 |
| Sum of Surplus and Rents | 5,418,106 | 5,289,047 | 5,198,697 | 5,119,489 | 5,327,955 | 5,265,427 | 5,205,830 | 5,351,116 | 5,301,100 | 5,253,896 |
| Change in Sum |  | 129,059 | 219,409 | 298,617 | 88,151 | 152,679 | 212,276 | 66,990 | 117,006 | 164,210 |
| Percentage Change |  | 2.39 | 4.05 | 5.51 | 1.63 | 2.82 | 3.92 | 1.24 | 2.16 | 3.03 |

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[a] See Part III, sections A and B for a discussion of definitions and computation methods.

Table G.3. Estimated Consumers' Surplus, Oregon and Non-Oregon Rents for Red Fescue in Supply Situation I Without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

|  | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Ban on Burning |  |  | Once in Three Years Burning |  |  | Alternate Year Burning |  |  |
|  |  | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Price per 100 lbs. | 26.50 | 26.8243 | 27.0826 | 27.3409 | 26.7167 | 26.8859 | 27.0611 | 26.6629 | 26.7920 | 26.9212 |
| Average variable cost per 100 lbs. | 6.7446 | 7.6375 | 8.3517 | 9.0660 | 7.3599 | 7.8160 | 8.2922 | 7.1911 | 7.5482 | 7.9053 |
| Agregate Output (100 lbs) | 261,640 | 255,433 | 250,477 | 245,521 | 257,498 | 254,194 | 250,890 | 258,531 | 256,053 | 253,575 |
| Oregon Output (100 lbs) | 67,240 | 64,653 | 62,347 | 60,172 | 65,428 | 63,978 | 62,528 | 65,882 | 64,794 | 63,707 |
| Non-Oregon Output (100 lbs) | 133,700 | 136,073 | 137,960 | 139,849 | 135,283 | 136,543 | 137,802 | 134,890 | 135,834 | 136,779 |
| Consumers' Surplus | 1,784,058 | 1,700,313 | 1,634,972 | 1,570,912 | 1,727,917 | 1,683,859 | 1,640,369 | 1,742,805 | 1,708,575 | 1,675,664 |
| Change in Consumers' Surplus |  | 83,745 | 149,086 | 213,146 | 56,141 | 100,199 | 143,689 | 42,253 | 75,483 | 105,394 |
| Percentage Change |  | 4.69 | 8.36 | 11.95 | 3.15 | 5.62 | 8.05 | 2.37 | 4.23 | 6.08 |
| Oregon Rents | 1,328,353 | 1,238,183 | 1,167,815 | 1,099,639 | 1,267,787 | 1,220,243 | 1,173,581 | 1,282,842 | 1,246,886 | 1,24,444 |
| Change in Oregon Rents |  | 90,170 | 160,538 | 228,714 | 60,566 | 108,110 | 154,772 | 45,511 | 81,467 | 116,909 |
| Percentage Change |  | 6.79 | 12.09 | 17.22 | 4.56 | 8.14 | 11.65 | 3.43 | 6.13 | 8.80 |
| Non-Oregon Rents | 1,222,018 | 1,265,769 | 1,301,130 | 1,337,008 | 1.251,130 | 1,274,540 | 1,298,157 | 1,243,866 | 1,261,342 | 1,278,951 |
| Change in Non-Oregon Rents |  | 43,751 | 79,112 | 114,990 | 29,112 | 52,522 | 76,139 | 21,848 | 39,324 | 56,933 |
| Percentage Change |  | 3.58 | 6.47 | 9.41 | 2.38 | 4.30 | 6.23 | 1.79 | 3.22 | 4.66 |
| Sum of Surplus and Rents | 4,334,429 | 4,204,265 | 4,103,917 | 4,007,559 | 4,246,834 | 4,178,642 | 4,112,107 | 4,268,513 | 4,216,803 | 4,166,059 |
| Change in Sum |  | 130,164 | 230,512 | 326,870 | 87,595 | 155,787 | 222,322 | 65,916 | 117,626 | 168,370 |
| Percentage Change |  | 3.00 | 5.32 | 7.54 | 2.02 | 3.59 | 5.13 | 1.52 | 2.71 | 3.88 |

[a] See Part II, sections A and B for a discussion of definitions and computation methods.

Table G.4. Estimated Consumers' Surplus, Oregon and Non-Oregon Rents for Chewings Fescue in Supply Situation I Without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

| | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ban on Burning | | | Once in Three Years Burning | | | Alternate Year Burning | | |
| | | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Price per 100 lbs. | 26.70 | 27.1674 | 27.54091 | 27.91443 | 27.0117 | 27.2607 | 27.5098 | 26.9339 | 27.1206 | 27.3074 |
| Average variable cost per 100 lbs. | 6.74460 | 7.63750 | 8.35174 | 9.06602 | 7.3399 | 7.8160 | 8.2922 | 7.1911 | 7.5482 | 7.9053 |
| Aggregate Output (100 lbs) | 117,600 | 115,072 | 113,044 | 111,016 | 115,918 | 114,565 | 113,213 | 116,340 | 115,326 | 114,312 |
| Oregon Output (100 lbs) | 68,000 | 66,027 | 64,443 | 62,864 | 66,680 | 65,628 | 66,455 | 67,009 | 66,220 | 65,430 |
| Non-Oregon Output (100 lbs) | 24,350 | 24,975 | 25,468 | 25,960 | 24,770 | 25,099 | 25,427 | 24,668 | 24,914 | 25,160 |
| Consumers' Surplus | 1,273,555 | 1,219,286 | 1,176,686 | 1,134,843 | 1,237,275 | 1,208,568 | 1,180,209 | 1,246,306 | 1,224,674 | 1,203,231 |
| Change in Consumers' Surplus | | 54,269 | 96,869 | 138,712 | 36,280 | 64,987 | 93,346 | 27,249 | 48,881 | 70,324 |
| Percentage Change | | 4.26 | 7.61 | 10.89 | 2.85 | 5.10 | 7.33 | 2.14 | 3.84 | 5.52 |
| Oregon Rents | 1,356,967 | 1,289,403 | 1,236,608 | 1,184,924 | 1,311,718 | 1,276,116 | 1,268,372 | 1,322,947 | 1,296,088 | 1,269,479 |
| Change in Oregon Rents | | 67,564 | 120,359 | 172,043 | 45,249 | 80,851 | 88,095 | 34,020 | 60,879 | 77,488 |
| Percentage Change | | 4.97 | 8.87 | 12.68 | 3.33 | 5.96 | 6.49 | 2.51 | 4.49 | 5.71 |
| Non-Oregon Rents | 225,021 | 236,634 | 246,061 | 255,665 | 232,763 | 238,980 | 245,269 | 230,845 | 235,473 | 240,148 |
| Change in Non-Oregon Rents | | 11,613 | 21,040 | 30,644 | 7,742 | 13,959 | 20,248 | 5,324 | 10,452 | 15,127 |
| Percentage Change | | 5.16 | 9.35 | 13.62 | 3.44 | 6.20 | 9.00 | 2.59 | 4.64 | 6.72 |
| Sum of Surplus and Rents | 2,855,543 | 2,745,373 | 2,659,355 | 2,575,432 | 2,781,756 | 2,723,664 | 2,694,350 | 2,800,098 | 2,756,235 | 2,712,858 |
| Change in Sum | | 110,220 | 196,188 | 280,111 | 73,787 | 131,879 | 161,193 | 55,445 | 99,308 | 142,685 |
| Percentage Change | | 3.86 | 6.87 | 9.81 | 2.58 | 4.62 | 5.64 | 1.94 | 3.48 | 5.00 |

[a] See Part III, sections A and B for a discussion of definitions and computation methods.

Table C.5. Estimated Consumers' Surplus, Oregon and Non-Oregon Rents for Merion Kentucky bluegrass in Supply Situation I Without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

| | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ban on Burning | | | Once in Three Years Burning | | | Alternate Year Burning | | |
| | | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Price per 100 lbs. | 68.90 | 69.2123 | 69.46657 | 69.72078 | 69.1064 | 69.2758 | 69.4454 | 69.0533 | 69.1806 | 69.3077 |
| Average variable cost per 100 lbs. | 7.52170 | 8.32690 | 8.97097 | 9.61509 | 8.0585 | 8.4679 | 8.9173 | 7.9243 | 8.2463 | 8.5684 |
| Aggregate Output (100 lbs) | 72,620 | 72,258 | 71973 | 71,687 | 72,377 | 72,187 | 71,996 | 72,437 | 72,294 | 72,151 |
| Oregon Output (100 lbs) | 17,600 | 17,336 | 17,133 | 16,930 | 17,483 | 17,285 | 17,150 | 17,463 | 17,362 | 17,260 |
| Non-Oregon Output (100 lbs) | 27,520 | 27,644 | 27,764 | 27,883 | 27,594 | 27,674 | 27,754 | 27,569 | 24,914 | 27,689 |
| Consumers' Surplus | 2,345,593 | 2,322,618 | 2,304,307 | 2,286,038 | 2,330,277 | 2,318,042 | 2,305,805 | 2,334,130 | 2,324,923 | 2,315,739 |
| Change in Consumers' Surplus | | 22,975 | 41,286 | 59,555 | 15,316 | 27,551 | 39,788 | 11,463 | 20,670 | 29,854 |
| Percentage Change | | 1.00 | 1.76 | 2.54 | 0.65 | 1.18 | 1.70 | 0.49 | 0.88 | 1.27 |
| Oregon Rents | 1,080,258 | 1,055,509 | 1,036,471 | 1,017,588 | 1,067,300 | 1,051,065 | 1,038,057 | 1,067,498 | 1,057,940 | 1,048,359 |
| Change in Oregon Rents | | 24,749 | 43,787 | 62,670 | 12,958 | 29,193 | 42,201 | 12,762 | 22,318 | 31,889 |
| Percentage Change | | 2.29 | 4.05 | 5.80 | 1.20 | 2.70 | 3.91 | 1.18 | 2.07 | 2.95 |
| Non-Oregon Rents | 803,309 | 811,245 | 818,294 | 825,345 | 808,514 | 813,002 | 817,705 | 806,850 | 810,364 | 813,883 |
| Change in Non-Oregon Rents | | 7,936 | 14,985 | 22,036 | 5,005 | 9,693 | 14,396 | [illegible],541 | 7,055 | 10,574 |
| Percentage Change | | 1.0 | 1.87 | 2.74 | 0.62 | 1.21 | 1.79 | 0.44 | 0.88 | 1.32 |
| Sum of Surplus and Rents | 4,229,160 | 4,189,372 | 4,159,072 | 4,128,971 | 4,206,091 | 4,182,109 | 4,161,567 | 4,208,478 | 4,193,227 | 4,177,981 |
| Change in Sum | | 39,788 | 70,088 | 100,189 | 23,069 | 47,051 | 67,593 | 20,682 | 35,933 | 51,179 |
| Percentage Change | | 0.94 | 1.66 | 2.37 | 0.55 | 1.11 | 1.60 | 0.49 | 0.85 | 1.21 |

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[a] See Part III, sections A and B for a discussion of definitions and computation methods.

Table G.6. Estimated Consumers' Surplus, Oregon and Non-Oregon Rents for Bentgrass in Supply Situation I without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

| | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ban on Burning | | | Once in Three Years Burning | | | Alternate Year Burning | | |
| | | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Price per 100 lbs. | 37.70 | 38.4155 | 38.9855 | 39.5559 | 38.1776 | 38.5579 | 38.9381 | 38.0588 | 38.3439 | 38.6290 |
| Average variable cost per 100 lbs. | 9.8754 | 11.3591 | 12.5460 | 13.7330 | 10.8645 | 11.6558 | 12.4471 | 10.6173 | 11.2107 | 11.8042 |
| Aggregate Output (100 lbs.) | 99,620 | 97,279 | 95,398 | 93,518 | 98,062 | 96,808 | 95,555 | 98,454 | 97,514 | 96,574 |
| Oregon Output (100 lbs.) | 70,480 | [illegible],267 | 66,492 | 64,717 | 69,007 | 67,823 | 66,640 | 69,377 | 68,488 | 67,601 |
| Non-Oregon Output (100 lbs.) | 3,960 | 4,086 | 4,182 | 4,281 | 4,045 | 4,110 | 4,17[illegible] | 4,025 | 4,074 | 4,123 |
| Consumers' Surplus | 1,505,298 | 1,435,135 | 1,380185 | 1,326,314 | 1,458,340 | 1,421,284 | 1,384,721 | 1,470,019 | 1,442,083 | 1,414,413 |
| Change in Consumers' Surplus | | 70,163 | 125,173 | 178,984 | 46,958 | 84,014 | 120,577 | 35,279 | 63,215 | 90,885 |
| Percentage Change | | 4.66 | 8.32 | 11.89 | 3.12 | 5.58 | 8.01 | 2.34 | 4.[illegible]0 | 6.04 |
| Oregon Rents | 1,961,088 | 1,847,043 | 1,758,015 | 1,671,183 | 1,884,792 | 1,824,577 | 1,765,359 | 1,903,809 | 1,858,295 | 1,813,387 |
| Change in Oregon Rents | | 114,057 | 203,063 | 289,895 | 76,286 | 136,501 | 195,719 | 57,269 | 102,783 | 147,691 |
| Percentage Change | | 5.82 | 10.35 | 14.78 | 3.89 | 6.96 | 9.98 | 2.92 | 5.24 | 7.53 |
| Non-Oregon Rents | 45,879 | 48,817 | 51,156 | 53.588 | 47,847 | 49,397 | 50,972 | 47,371 | 48,528 | 49,700 |
| Change in Non-Oregon Rents | | 2,938 | 4,277 | 7,709 | 1,968 | 3,518 | 5,093 | 1,492 | 2,649 | 3,821 |
| Percentage Change | | 6.40 | 11.50 | 16.80 | 4.29 | 7.67 | 11.10 | 3.25 | 5.77 | 8.33 |
| Sum of Surplus and Rents | 3,512,255 | 3,330,995 | 3,189,356 | 3,051,085 | 3,390,974 | 3,295,258 | 3,201,052 | 3,421,199 | 3,348,906 | 3,277,500 |
| Change in Sum | | 181,240 | 322,899 | 461,170 | 121,276 | 216,997 | 311,203 | 91,056 | 163,349 | 234,755 |
| Percentage Change | | 5.16 | 9.19 | 13.13 | 3.45 | 6.18 | 8.86 | 2.59 | 4.65 | 6.68 |

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[a] See Part III, sections A and B for a discussion of definitions and computation methods.

Table G.7. Estimated Consumer's Surplus, Oregon and Non-Oregon Rents for Various Grass Seeds in Supply Situation II without and with Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

| | | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ban on Burning | | | Once in Three Years | | | Alternate Year Burning | | |
| Seed Type | Initial Situation | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| Ryegrass | | | | | | | | | | |
| Price per 100 lbs. | 6.8600 | | | | | | | | | |
| Average variable costs per 100 lbs. | 2.6800 | 3.0939 | 3.4249 | 3.7460 | 2.9595 | 3.1766 | 3.3974 | 2.8870 | 3.0525 | 3.2180 |
| Oregon output (100 lbs.) | 1,585,850 | | | | | | | | | |
| Change in Oregon rents | | 656,383 | 1,181,363 | 1,706,438 | 437,584 | 787,565 | 1,137,625 | 328,192 | 590,682 | 853.219 |
| Percentage change in Oregon rents | | 9.90 | 17.82 | 25.74 | 6.60 | 11.88 | 17.16 | 4.95 | 8.91 | 12.87 |
| Tall Fescue | | | | | | | | | | |
| Price per 100 lbs. | 12.0800 | | | | | | | | | |
| Average variable costs per 100 lbs. | 4.6678 | 5.2588 | 5.7316 | 6.2044 | 5.0618 | 5.3770 | 5.6922 | 4.9633 | 5.1997 | 5.4361 |
| Oregon output (100 lbs.) | 102,480 | | | | | | | | | |
| Change in Oregon rents | | 60,566 | 109,020 | 157,475 | 40,377 | 72,680 | 104,984 | 30,283 | 54,510 | 78,737 |
| Percentage change in Oregon rents | | 7.97 | 14.35 | 20.73 | 5.32 | 9.57 | 13.82 | 3.99 | 7.18 | 10.37 |
| Red Fescue | | | | | | | | | | |
| Price per 100 lbs. | 26.5000 | | | | | | | | | |
| Average variable costs per 100 lbs. | 6.7446 | 7.6375 | 8.3517 | 9.0660 | 7.3399 | 7.8160 | 8.2922 | 7.1911 | 7.5482 | 7.9053 |
| Oregon output (100 lbs.) | 67,240 | | | | | | | | | |
| Change in Oregon rents | | 60,039 | 108.064 | 156,092 | 40,012 | 72,043 | 104,062 | 30,019 | 54,032 | 78,046 |
| Percentage change in Oregon rents | | 4.52 | 8.14 | 11.75 | 3.01 | 5.42 | 7.83 | 2.26 | 4.07 | 5.86 |
| Chewings Fescue | | | | | | | | | | |
| Price per 100 lbs. | 26.7000 | | | | | | | | | |
| Average variable costs per 100 lbs. | 6.7446 | 7.6375 | 8.3517 | 9.0660 | 7.3399 | 7.8160 | 8.2922 | 7.1911 | 7.5482 | 7.9053 |
| Oregon output (100 lbs.) | 68,000 | | | | | | | | | |
| Change in Oregon rents | | 60,712 | 109,286 | 157,857 | 40,546 | 72,857 | 105,238 | 30,359 | 54,643 | 78,928 |
| Percentage change in Oregon rents | | 4.47 | 8.05 | 11.63 | 2.99 | 5.37 | 7.76 | 2.24 | 4.03 | 5.82 |
| Merion-Kentucky Bluegrass | | | | | | | | | | |
| Price per 100 lbs. | 68.4000 | | | | | | | | | |
| Average variable costs per 100 lbs. | 7.5217 | 8.3269 | 8.9710 | 9.6151 | 8.0585 | 8.4679 | 8.9173 | 7.9243 | 8.2463 | 8.5684 |
| Oregon output (100 lbs.) | 27,520 | | | | | | | | | |
| Change in Oregon rents | | 22,159 | 39,884 | 57,610 | 14,773 | 26,589 | 38,407 | 11,080 | 19,942 | 28,805 |
| Percentage change in Oregon rents | | 2.05 | 3.89 | 5.33 | 1.37 | 2.46 | 3.56 | 1.03 | 1.85 | 2.67 |
| Bentgrass | | | | | | | | | | |
| Price per 100 lbs. | 37.70 | | | | | | | | | |
| Average variable costs per 100 lbs. | 9.8754 | 11.3591 | 12.5460 | 13.7330 | 10.8645 | 11.6558 | 12.4471 | 10.6173 | 11.2107 | 11.8042 |
| Oregon output (100 lbs.) | 70.480 | | | | | | | | | |
| Change in Oregon rents | | 104,571 | 188,225 | 271,881 | 69,714 | 125,484 | 181,254 | 52,286 | 94,113 | 135,940 |
| Percentage change in Oregon rents | | 5.33 | 9.60 | 13.86 | 3.55 | 6.40 | 9.24 | 2.67 | 4.80 | 6.93 |

[a] See Part III, sections A and B for a discussion of definitions and computation methods.

Table G.8 Estimated Consumer's Surplus, Oregon and Non-Oregon Rents for Various Grass Seeds in Supply Situation III Without and With Alternative Open Field Burning Control Policies at Varying Costs per Acre for the Mobile Field Sanitizer[a]

| Seed Type | Initial Situation | Open Field Burning Control Policies and Mobile Sanitizer Cost per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ban on Burning | | | Once in Three Years | | | Alternate Year Burning | | |
| | | $5 | $9 | $13 | $5 | $9 | $13 | $5 | $9 | $13 |
| **Ryegrass** | | | | | | | | | | |
| Price per 100 lbs. | 6.86 | | | | | | | | | |
| Average variable costs per 100 lbs. | 2.68 | 3.0939 | 3.42494 | 3.74604 | 2.9595 | 3.1766 | 3.3974 | 2.8870 | 3.0525 | 3.2180 |
| Oregon output (100 lbs.) | 1,585,850 | 1,409,832 | 1,270,417 | 1,131,639 | 1,467,815 | 1,375,084 | 1,282,311 | 1,496,765 | 1,427,227 | 1,357,731 |
| Change in Oregon rents | | 1,319,285 | 2,264,844 | 3,104,929 | 903,641 | 1,563,869 | 2,188,723 | 682,206 | 1,194,686 | 1,683,997 |
| Percentage change in Oregon rents | | 19.90 | 34.17 | 46.84 | 13.63 | 23.59 | 33.02 | 10.29 | 18.02 | 25.40 |
| **Tall Fescue** | | | | | | | | | | |
| Price per 100 lbs. | 12.08 | | | | | | | | | |
| Average variable costs per 100 lbs. | 4.6678 | 5.2588 | 5.73162 | 6.2044 | 5.0618 | 5,3770 | 5.6922 | 4.9633 | 5.1997 | 5.4361 |
| Oregon output (100 lbs.) | 102,880 | 93,563 | 86,422 | 79,282 | 96,537 | 92,779 | 87,017 | 98,025 | 94,455 | 90,855 |
| Change in Oregon rents | | 96,408 | 211,000 | 293,794 | 82,104 | 133,723 | 203,775 | 62,005 | 109,742 | 155,791 |
| Percentage change in Oregon rents | | 12.69 | 27.78 | 36.68 | 10.81 | 18.13 | 26.83 | 8.16 | 14.45 | 20.51 |
| **Red Fescue** | | | | | | | | | | |
| Price per 100 lbs. | 26.50 | | | | | | | | | |
| Average variable costs per 100 lbs. | 6.7446 | 7.6375 | 8.3517 | 9.0660 | 7.3399 | 7.8160 | 8.2922 | 7.1911 | 7.5462 | 7.9053 |
| Oregon output (100 lbs.) | 67,240 | 62,975 | 59,568 | 56,161 | 64,395 | 62,123 | 59,852 | 65,105 | 63,401 | 61,698 |
| Change in Oregon rents | | 140,487 | 247,297 | 349,243 | 94,536 | 167,649 | 238,581 | 71,244 | 126,788 | 181,098 |
| Percentage change in Oregon rents | | 10.58 | 18.62 | 26.29 | 7.12 | 12.62 | 17.96 | 5.36 | 9.54 | 13.63 |
| **Chewings Fescue** | | | | | | | | | | |
| Price per 100 lbs. | 26.70 | | | | | | | | | |
| Average variable costs per 100 lbs. | 6.7446 | 7.6375 | 8.3517 | 9.0660 | 7.3399 | 7.8160 | 8.2922 | 7.1911 | 7.5482 | 7.9053 |
| Oregon output (100 lbs.) | 68,000 | 65,668 | 60,546 | 57,235 | 65,236 | 63,029 | 60,822 | 65,925 | 64,270 | 62,615 |
| Change in Oregon rents | | 105,171 | 246,053 | 347,686 | 93,989 | 166,729 | 237,369 | 70,839 | 126,079 | 180,137 |
| Percentage change in Oregon rents | | 7.75 | 18.13 | 25.62 | 6.93 | 12.29 | 17.49 | 5.22 | 9.29 | 13.27 |
| **Merion-Kentucky Bluegrass** | | | | | | | | | | |
| Price per 100 lbs. | 68,90 | | | | | | | | | |
| Average variable costs per 100 lbs. | 7.5217 | 8.3269 | 8.9710 | 9.6151 | 8.0585 | 8.4679 | 8.9173 | 7.9243 | 8.2463 | 8.5684 |
| Oregon output (100 lbs.) | 27,520 | 17,173 | 16,838 | 16,502 | 17,376 | 17,090 | 16,446 | 7,383 | 17,215 | 17,048 |
| Change in Oregon rents | | 40,036 | 71,173 | 101,938 | 23,076 | 47,473 | 93,782 | 20,317 | 36,105 | 51,725 |
| Percentage change in Oregon rents | | 3.71 | 6.59 | 9.44 | 2.14 | 4.39 | 8.68 | 1.88 | 3.34 | 4.79 |
| **Bentgrass** | | | | | | | | | | |
| Price per 100 lbs. | 37.70 | | | | | | | | | |
| Average variable costs per 100 lbs. | 9.8754 | 11.3591 | 12.5460 | 13.7330 | 10.8645 | 11.6558 | 12.4471 | 10.6173 | 11.2107 | 11.8042 |
| Oregon output (100 lbs.) | 70,480 | 66,208 | 62,791 | 59,374 | 67,632 | 65,354 | 63,075 | 68,344 | 66,635 | 64,926 |
| Change in Oregon rents | | 217,100 | 381,634 | 538,059 | 146,141 | 258,987 | 368,252 | 110,133 | 195,964 | 279,766 |
| Percentage change in Oregon rents | | 11.07 | 19.46 | 27.44 | 7.45 | 13.21 | 18.78 | 5.62 | 9.99 | 14.27 |

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[a] See Part III, sections A and B for a discussion of definitions and computation methods.

# APPENDIX H

# Effects of Air Quality Variation on Tourist Behavior*

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* The work upon which this report is based was performed pursuant to Contract CPA 70-117 with the Environmental Protection Agency.

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# I. INTRODUCTION

Mark Twain once observed that everybody talks about the weather, but nobody does anything about it. A similar generalization might apply to air pollution. That is, everybody talks about air pollution. The question is, do they do anything different as a result of it? Do people alter their behavior as a result of air pollution? If behavior is altered, is there any reason to believe that social welfare has been affected negatively? If it has, what is the magnitude of social cost and/or economic loss associated with this change in behavior? The research results offered below constitute an attempt to respond to these questions. The focus of the research will be rather narrow in that it will not exhaust all the possible ways that air pollution might affect behavior. However, if the existence of some social costs associated with air pollution can be identified, and if a preliminary estimate of the magnitude of these costs can be obtained, the research should suggest other avenues for continued inquiry.

Prior to testing empirical hypotheses about the effects of air pollution on individuals it is necessary to establish the theoretical existence of such effects. That is, it is necessary to provide an internally consistent theoretical model that generates meaningful hypotheses relating the behavior of individuals to air pollution. Appendix I of this report provides a model that does produce meaningful hypotheses. In that model, individuals are treated as utility maximizers in the traditional manner in economic analysis. The problem is set up as a nonlinear programming problem in which there is both an income and a time constraint. The consumer combines market commodities (purchased with his budget) with time (in intervals of varying length) and he produces consumption activities. These activities are the arguments in the utility function.

To model the resource allocation problem of an individual is relatively easy. To relate air pollution to this utility maximization, production-consumption problem is more difficult. As noted in Appendix I, it is customary to treat air quality as constant and effectively independent of any optimal consumption set. If one recognizes the fact that air quality does vary and takes casual remarks about individual preferences for better as opposed to worse air quality at face value, it is still not obvious how to relate variation in air quality to the utility maximization problem. One possible tack would be to include a variable called "pollution" in the utility function and assume that pollution affects the utility function in certain negative ways. Then one might produce hypotheses about the effects of air quality variation. Unfortunately, there is no market for pollution. There are no explicit prices for pollution. Hence it is not possible to observe individuals consuming more or less pollution as the quality (price) of air varies. Any hypotheses generated by taking this tack would be operationally unmeaningful.

The approach utilized in the analysis of Appendix I is less direct than trying to put pollution in the utility function, but it does produce meaningful and potentially testable hypotheses. That analysis is expressed in a comparative static framework in which the consumer seeks out an optimal allocation of his budget and his time. At equilibrium, the marginal utilities of all consumption activities are fixed; the values of the fixed marginal utilities are a product of the consumer's preferences for the respective activities and the amounts of the activities that are presently being produced and consumed.

It is usual in the analysis of consumer behavior to subject any equilibrium to the shock of changing either income or prices. The comparative static framework, then, allows one to compare different equilibrium positions in order to derive qualitative information on the effects of that shock. In the analysis of Appendix I, the shock is provided by a change in air quality that is assumed to affect the marginal utilities in the system in a predictable manner. If air quality goes down, the marginal utilities in the system either fall or remain unchanged. If air quality goes up, the opposite set of sign changes in the vector of marginal utilities takes place. In this framework, one can vary air quality and the analysis will produce certain implications about changes in behavior. The observable theoretical effects of air quality variation will be reflected in variance in the amount of various consumption activities consumed and, hence, in variance in the amounts of certain market commodities purchased. Given certain a priori information about the relationship between air quality and various consumption activities, one can test the hypotheses generated in a meaningful and positive manner.

The hypotheses suggested by the model in Appendix I, of both the operating and theoretical type, are:

1. Variation in air quality may have no direct effects on the consumption of some activities. The result of this may be that some activities appear to be independent of air quality.

2. There is a subset of consumption activities whose level of consumption varies directly with the quality of the air.

3. By implication, since consumption activities are produced by combining market commodities and time, and since market commodities are purchased from a binding budget constraint, and since there is a binding time constraint, variation in the consumption level of one set of activities (i.e., those activities whose consumption level varies directly with air quality) will produce variation in another set of consumption activities whose consumption level varies inversely with air quality.

4. Since air quality is imposed as an exogenous variable unrelated to either the income or time constraints, any impact on the set of optimal consumption activities must, by implication, produce a negative welfare effect.

5. Lastly, since the theory predicts that a deterioration in air quality will lead to a switching in the set of consumption activities produced and consumed by consumers, by implication, there should be observable market impacts.

These hypotheses suggest that air quality does make a difference in what people do and in their welfare. The hypotheses are conceptually testable. Put otherwise, the hypotheses suggest that variation in air quality should produce social costs which are potentially measurable. The theory dictates that these hypotheses be tested indirectly. As it turns out, there are substantial difficulties in doing this. These difficulties can be attributed to more than just the directness of the testing procedures.

The analysis of Appendix I draws upon the work of Gary Becker who, in his 1965 article on the "Theory of The Allocation of Time", viewed the consumer as literally producing consumption activities by combining market commodities and time in different combinations so as to create an activity he then consumes. Each activity's production is limited by a production function. While this is theoretically plausible and intuitively appealing, it unfortunately provides a source of difficulty for purposes of empirical analysis. There are as many production functions as there are consumer activities and there are no empirical estimates of them.

Aside from the lack of *a priori* information about the consumption activity production functions, a second difficulty arises from another lack of *a priori* information. The comparative static analysis of Appendix I is amenable to the imposition of a shock on the equilibrium configuration such as would be provided by assuming that a change in air quality affects the relevant marginal utilities in the configuration. This procedure is mathematically and theoretically valid as well as intuitively plausible. But there is a substantial difference between hypothesizing a general and unspecific change in the vector of marginal utilities on the initial and theoretical equilibrium configuration, and quite another thing to be faced with the requirement of specifying exactly which marginal utilities are affected by this change in air quality. If one knew that a deterioration in air quality reduced the marginal utilities of a particular subset of consumption activities, he could predict that the consumption of those activities and the consumption of the associated market commodities would decline *ceteris paribus*. The theory of consumer behavior would suggest, however, that if a particular subset of activities faced diminished demand there should be another subset of activities that act as substitutes for the first subset and which should be confronted by a positive change in demand. There is, then, the dual problem of anticipating which activities would be affected negatively by a deterioration in air quality and which activities would be affected positively as they perform the role of substitutes. Prior research is not helpful at this juncture.

## II. RESEARCH DESIGN

The consumption activities we are concerned with can be specified in terms of the amounts of market commodities (or public facilities) and time required to produce a given kind of consumption activity. This is suggested in general form in equation (2) of Appendix I. There, we have assumed that the proportions are fixed or, alternatively, that the technologies are linear. Unfortunately, there are as many production functions as there are consumption activities and there are no prior estimates of the multitude of functional characteristics. A preliminary empirical testing procedure may be suggested by the linearity assumption employed with respect to the production functions.

Consider a production function such as the following:

$$Z_j = f_j (x_{1j}, x_{2j}, T_{1j}, T_{2j}) .$$

This hypothetical activity, $Z_j$, requires two market commodities, $x_1$ and $x_2$, and an interval of time from two hours of the day. Drawing upon equation (3) of Appendix I, each unit of $Z_j$ produced and consumed would require the expenditure of $p_1b_{1j} + p_2b_{2j}$ of dollars and $t_{1j} + t_{2j}$ of time. Variation in the amount of $Z_j$ produced and consumed would require direct variation in the amounts of $x_1$ and $x_2$ as well as time. Even given that one did not know the precise technical amounts of $x_1$ and $x_2$ or time required per unit of $Z_j$, if he knew that these market commodities were involved in the production and consumption of this activity he would predict that any variation in the consumption of this activity would produce corresponding and positively related variation in the amounts of those activities purchased.

Suppose that a particular consumption activity required the use of, among other things, a portion of the facilities at a public swimming pool? Or suppose it required the use of a portion of the facilities of a golf course, or a public camp ground, or a portion of the state capitol facilities? Regardless of the name of the consumption activity, and regardless of the other market commodities or public facilities required in the production and consumption of the activity, and regardless of the strict proportions of time required per unit of the activity, if one could predict variation in the amount of the activity consumed, he could predict variation in the use of those particular facilities. Utilizing this proposition and the operating hypothesis about the relationship between air quality and a particular set of consumption activities, it is possible to indirectly test that hypothesis by relating the variation in air quality to the variation in use or attendance at particular facilities that might be predicted to be associated with the activities in question. Previous research in this project has utilized data on levels of low visibility for the cities of Salem and Eugene, Oregon, for the years 1969, 1970, and 1971. Also, data are available on a limited number of public or private recreation-related facilities in these cities. In particular, for the City of

Salem, daily attendance records over the relevant period are available for the number of tourist visits to the State Capitol as well as the attendance at the public swimming pools. Similarly, for the City of Eugene, daily records are available for the indoor and outdoor swimming pools, one private golf course and for one state park located in the immediate proximity of Eugene. By hypothesis, the attendance at these facilities should be affected by, among other things, the quality of the air. Assuming that low visibility is a meaningful proxy for air quality, we can partially and indirectly test the hypothesized relationships here using data on low visibility. This procedure is incorporated as one part of this research design.

On a priori grounds we would predict that the relationship between attendance at swimming pools (at least outdoor swimming pools), golf courses, and state parks should be positively related to air quality. Using the measure of low visibility as an index of air quality, this would maintain the positive predicted relationship. On the other hand, an activity which involves visiting the State Capitol (an "indoor" activity) or the attendance at an indoor swimming pool might be regarded as a substitute for activities that are expressly out of doors. Theoretically, one might predict the relationship between air quality and the attendance at this class of facilities would be inverse. These predictions are consistent with the analysis and hypotheses provided above and in Appendix I.

Statistical analysis of the above hypotheses would not, unfortunately, prove or disprove the propositions. Daily attendance or use data are available for only a small number of facilities that might theoretically be related to activities that are correspondingly related to air quality. In particular, data are not available on the wide variety of commodities or facilities associated with activities that would be substitutes for activities directly related to air quality. This is true for commodities and facilities purchased or used in the areas of air pollution as well as those purchased or used in areas away from the pollution concentrations. Even given the data limitations, however, it still seemed reasonable to examine what statistical relationships might be suggested by available data in order to suggest the merit of possibly generating original data for future testing purposes. This analysis is provided in section III below.

The second portion of the empirical research design involves interviewing 401 out-of-state parties traveling in Oregon for pleasure during the month of August, 1971. This empirical procedure was suggested in part by the character of the hypotheses outlined above. It was strongly influenced by the fact that Oregon attracts approximately 7.6 million people (in 2.8 million parties) a year who travel in Oregon for pleasure and these people are presumed to be drawn to Oregon by the quality and quantity of out-of-door type facilities and activities available for use and consumption in the state. These out-of-state parties can be identified in a number of ways. The total number of people visiting Oregon on an annual basis for vacation purposes exceeds the total state population by a factor of 3.8.

They make substantial expenditures on commodities and facilities involved in the consumption of out-of-door activities. If, in fact, air quality makes a difference in the behavior of people and hence on the kind of activities they consume, since there is such a large number of potentially identificable people drawn to the state on an annual basis who utilize activities theoretically related to air quality, it makes some sense to employ an empirical technique that draws upon these facts. Appendix II of this report outlines selected data on tourist travel in Oregon taken from the 1971 Out-of-State Tourist Revenue Study prepared by the Oregon State Division of Highways.

The lack of a priori information about the consumer activities production functions has, as indicated above, complicated the empirical problem. However, the flow of a large number of out-of-state tourists traveling in the state, particularly during the summer months who utilize facilities and purchase commodities that are involved in the type of activities theoretically positively related to air quality, provides a potentially large source of data on the effects of air quality variation. One theoretical and empirical question for which there is no a priori information relates to whether tourists are "tracked" in their consumption behavior such that variation in air quality will affect the selection of consumption activities in a small region, or do these consumers have sufficient flexibility to lead them to look some distance for available alternative activities? The latter alternative would suggest the effects of air quality variation are quite strong. It was decided to attempt to determine the answer to this question as well as provide an indirect test of the effects of air quality variation by employing an interview technique on a sample of out-of-state tourists during the month of August when the air pollution problem in the Willamette Valley is potentially and empirically the greatest.

In Appendix III the questionnaire employed in this empirical research is provided. It was administered to 401 out-of-state tourists traveling in Oregon in the interval August 19 through August 31, 1971. The questionnaire is designed to:

1. Select for out-of-state persons traveling in Oregon for pleasure.
2. Identify the type of area from which they came.
3. Identify the routes they planned to travel prior to embarking on their vacation trip.
4. Identify the type of activities they planned to enjoy on their vacation prior to departing home and to obtain an idea of the relative amounts of time they planned to allocate to each activity.
5. Determine whether those pre-vacation plans have changed enroute.
6. Determine why any such changes occurred.
7. Focus on the possible impact of air pollution or air quality variation on those travel plan changes.

8. Estimate the dollar value or cost of those changes.

9. Determine the perceptions of the relative amounts of air pollution in Oregon, vis-a-vis areas from which they came.

10. Obtain various demographic data on the population sampled.

The sample frame chosen for obtaining these interviews is the set of out-of-state parties traveling in Oregon for pleasure who stopped at a particular set of probability determined motels or safety rest areas overnight. This sample frame was further divided equally between the Willamette Valley on the one hand and a proportionally determined and randomly selected set of motels and safety rest areas located on the Oregon Coast and in the central Oregon region. This within-frame dichotomy was suggested by the fact that it is the Willamette Valley that has the largest actual and potential air pollution problem at any time of the year and particularly during the summer, while the coastal and interior regions are essentially without an air pollution problem at this time. Dividing the sample frame between the so-called "pollution" and "nonpollution" areas should permit a maximal opportunity for observing whether air quality variation does, in fact, make a difference.

For purposes of determining exactly which motels and safety rest areas would be involved in the actual sample design, the following procedure was employed. The so-called high pollution region which is affected by field burning smoke as well as other sources of air borne pollutants can be roughly identified as the area from Cottage Grove at the southern end of the Willamette Valley to Portland. This region is spanned in its entirety by Interstate Highway 5. Portland is located on the northern border of the state and is the center of business activity. The motels and hotels in Portland are expected to be utilized by tourists, traveling businessmen, and state residents passing through Portland for a variety of reasons. Since there are no data on the relative proportions of these different types of potential users of the Portland area motels and hotels and given its location in the state, it was decided to treat Portland as a special case and exclude it from the sample frame. Even with this exclusion, there remains a large number of motels located in cities and towns within the Willamette Valley area. In deference to pragmatism and budgetary constraint, for the motel portion of the sample frame it was decided to utilize the set of motels listed in the combined lists provided by the Oregon Motel Hotel Association Touring Guide and the AAA Tour Book for cities or towns or motels listed along Interstate 5 in the relevant region. The combined list of motels provided by these two tour books is large but clearly excludes many motels even in the cities and towns covered. However, these tour books are tourist oriented and the listed motels provide substantial variety in room prices. For these reasons, along with budgetary and other pragmatic considerations, the set was delimited to the combined list offered by the tours book. All safety rest areas in this region of the Willamette Valley were included in the potential frame.

The 200 interviews obtained from the so-called "non-polluted" portion of the state were obtained from the central and the coastal regions. Determination of the set of motels and safety rest areas included in the frame was based partly on pragmatism extending from a budget constraint and partly on the basis of population and traffic pattern considerations. For the Central Oregon area, Highway 97 provided the guideline for locating motels and safety rest areas. Again, the combined list of motels provided by the Oregon State Motor Hotel Association and the AAA tour books extending from Klamath Falls at the south to The Dalles at the north provided the potential sample frame. Safety rest areas along this length of highway were included in the potential frame. Given knowledge of the number of units at the potential motels and the number of parking spaces at the potential safety rest areas, the precise numbers of interviews to be taken at each motel or safety rest area was determined on a random basis.

On the Oregon Coast, the highway that provided the guide for selecting motels and safety rest areas was Highway 101. The relevant range of this highway was chosen to extend from Coos Bay at the south to Astoria at the north. The choice of Coos Bay as the southern boundary was based primarily on budgetary constraint considerations. The same procedure for selecting motels and determining the number of interviews to be taken at particular motels or safety rest areas was identical to the central and Willamette regions.

The map provided in Figure 1 outlines the portions of I-5, Highway 97, and Highway 101 covered in the sampling procedure. The portions of these highways included in the sample design are marked in heavy black ink.

A copy of the questionnaire employed in this interview procedure is provided in Appendix III. The questionnaire consists of 33 questions which are designed to permit indirect testing of hypotheses relating to:

1. The impact of air quality variation on the pattern of consumption activities consumed.
2. The economic costs of these impacts.
3. The relative magnitude of air pollution in Oregon vis-a-vis other areas.
4. The type of person or family unit influenced by air quality variation.
5. The degree to which vacation travelers are "tracked" in their travels or whether they change travel plans as a result of perception or parameter changes enroute.

The data generated and the analysis of those data are provided in section IV.

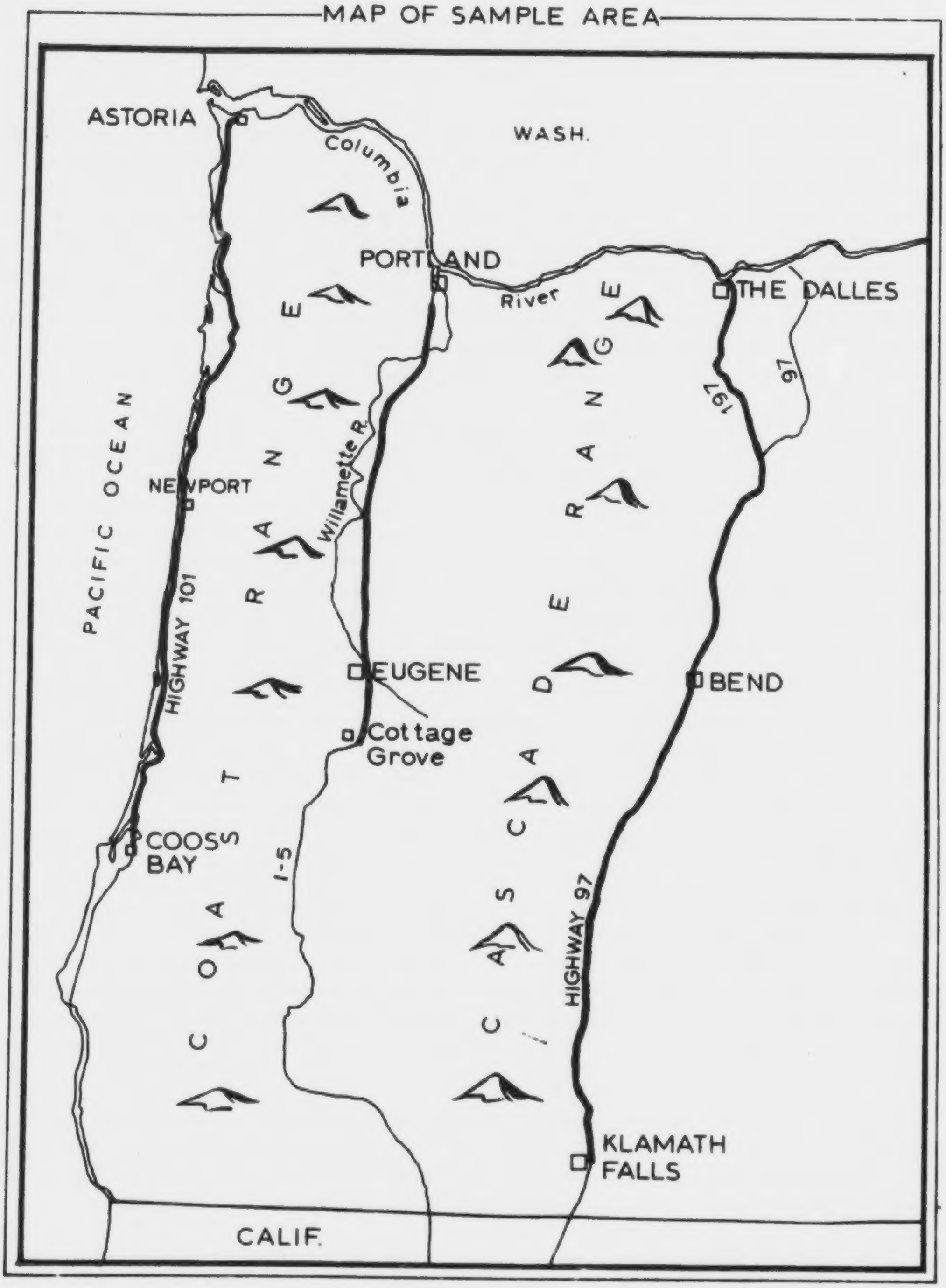
MAP OF SAMPLE AREA
ASTORIA
WASH.
Columbia
PORTLAND
River
THE DALLES
197
97
PACIFIC OCEAN
NEWPORT
Willamette R.
HIGHWAY 101
EUGENE
Cottage Grove
BEND
COOS BAY
I-5
COAST RANGE
CASCADE RANGE
HIGHWAY 97
KLAMATH FALLS
CALIF.

Figure 1. Map outlining the portions of I-5, Highway 97, and Highway 101 covered in the sampling procedure. The portions of these highways included in the sample design are marked in heavier black.

## III. REGRESSION RESULTS

In the last section, a plan for relating attendance or use at certain public or private facilities in the cities of Eugene and Salem was outlined. The objective of that procedure was to attempt to perceive whether relationships anticipated on a priori grounds between certain dependent variables on the one hand and an index of air quality as well as a limited number of other determining variables on the other hand is supported by empirical data. In general terms, we are postulating a relationship between a dependent variable, Y, and three independent variables, $X_i$. In general form, this functional relationship can be expressed $Y = F(X_1, X_2, X_3)$. For lack of other information, the function, F, is in each case assumed to be linear.

In all, there are seven relationships hypothesized. For Eugene, there are five relationships. For Salem, there are two. The five dependent variables used for the Eugene area are (1) the number of camper units staying overnight at Armitage State Park, located on the outskirts of Eugene, (2) the number of "nine holes" played at Green Acres Golf Course, Inc., (3) the number of people attending the two public indoor swimming pools in Eugene, (4) the number of people attending the two outdoor public swimming pools in Eugene, and (5) the number of people attending all public swimming pools in Eugene; this is a total of the indoor and outdoor attendance. The availability of daily attendance or use data on public or private facilities is very limited. For State parks in any relevant region, there are daily counts of the number of camper units. Armitage is the only State park in the immediate area. In the Eugene area there are approximately ten public or private golf courses. Of this set, only one claimed to have data on the number of people using the facilities daily that could be regarded as accurate. In most cases, signup sheets were not regarded as an accurate indication of the number of people playing golf on a particular day. Regarding attendance at the public swimming pools in Eugene, since there are two indoor and two outdoor pools and since attendance at these types of facilities might theoretically be different under variation of air quality, it was decided to initially treat the indoor and outdoor pool attendance separately. Data on these dependent variables is on a daily basis extending over a period from July 15 through either September 30, 1970, or in the case of the swimming pools, through Labor Day, as the pools close after that date.

For Salem, the two dependent variables are (1) the number of visitors recorded at the Oregon State Capitol at the information counter, and (2) the total attendance at the three public outdoor swimming pools. These data, too, are daily and extend over the same period as do those for Eugene.

The independent variables in each case are definitionally the same. Data were obtained for visibility as measured at the Eugene and Salem airports. The low measurement was taken as the first independent variable. Low visibility is, again, used as an index of air quality. This is an appropriate choice on a priori grounds, given the fact that the primary source of air pollution during the period under consideration is the smoke from burning grass seed fields in the Willamette Valley. The disadvantage of this index of air quality relates to the manner in which it is measured at the airports. The measurement technique involves a visual and hourly evaluation of maximum visibility over 360° on the horizon and measured against known distances between the airport on one hand and certain pre-established markers on the other. Given the location of the airport particularly at Eugene, the measurement technique may produce inaccurate estimates of visibility in the respective cities. However, this is the only meaningful index of air quality presently available for these cities. It is an index that has been used in other empirical work in this study.* Hence, low visibility as measured at the airports was used as the index of air quality.

Attendance or use at the facilities reflected in the set of dependent variables might, theoretically, be related to air quality. However, since these are facilities that might be classed as recreation and, in many cases, out-of-door type, attendance or use might also be theoretically affected by the temperature. For this reason, high temperature at the respective cities was included as an independent variable. This datum was selected from a set of daily observations taken at the respective airports.

Also, it seemed reasonable to dichotomize the week between the work days of Monday through Friday on one hand and the weekend days of Saturday and Sunday on the other. The purpose of imposing a dichotomy is explained by the fact that most of the dependent variables can be regarded as being affected by the behavior of local populations. Therefore, it seems reasonable to recognize the influence of the institutionalized work week. The independent variable reflecting this dichotomized version of "Day" is a dummy variable which takes on the value of 0 for days in the Monday through Friday range and the value of 1 for Saturday and Sunday. Given the fact that the functional forms are assumed linear in the regression analysis, this dummy variable has the effect of just shifting the regression.

It should be clear that this regression model subsumes everything that usually comes under "taste" under the functional operator. The independent variables or functional arguments, i.e., low visibility, high temperature, day - operate in the model as marginal and exogenous independent factors that influence the behavior of people. Clearly these three arguments are not the sole determinants of attendance or use at the public and private facilities in operation. They are, again, treated as marginal determinants of that behavior.

What are the qualitative results that one would expect from these regressions? Table III.1 below illustrates the qualitative set of relationships that are hypothesized for the seven regressions which were performed. The supporting rationale is as follows:

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* This work related to the Pollution Production Function.

## TABLE III.1

Participation in or Use of a Selected Set of Dependent Variables Against Visibility, Temperature and Day; Predicted Regression Signs

| Regression Number | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Dependent Variable* | A | G | $P_I$ | $P_O$ | $P_T$ | CV | P |
| Independent Variable | | | | | | | |
| Low visibility | + | + | - | + | + | - | + |
| High temperature | + | + | + | + | + | + | + |
| Day | + | + | - | - | - | + | - |

---

* Dependent variables are: A = daily attendance at Armitage State Park, G = number of nine holes of golf played at Green Acres Golf Course, $P_I$ = attendance at Eugene indoor swimming pools, $P_O$ = attendance at Eugene swimming pools, $P_T$ = total indoor and outdoor swimming pool attendance at Eugene, CV - number of daily registered visitors at State Capitol, P = total daily attendance at Salem public outdoor swimming pools.

1. The Armitage State Park variable, A, measures the number of camper units staying overnight at that facility measured on a daily basis. On a priori grounds which accept the proposition that camping is related to the environmental quality, we would expect this variable to be positively related to low visibility, positively related to high temperature, and positively related to the day variable. Given the location of Armitage, being on the McKenzie River and very close to Eugene, the attaraction of this facility may be different than that of another state park located in more remote areas. That is, the Armitage facility may be more of an overnight accommodation for visitors to the area than a purely camping and outdoor recreation oriented facility. Therefore, the coefficient for low visibility might be expected to be smaller than the coefficients for the other two variables.

2. The golf variable, G, is viewed as functionally similar to the Armitage State Park or the outdoor swimming pool variables. That is, it reflects an outdoor type activity that, on a priori grounds, is influenced by the quality of the environment. Therefore, we would predict a positive relationship between the golf variable and low visibility, a positive relationship with high temperature, and a positive relationship with the day variable.

3. The indoor swimming pool variable, $P_I$ is viewed as offering an interesting cross-check on the role of air quality on recreation type activities. Eugene has two indoor pools along with two outdoor pools. Theoretically we should observe a difference in the impact of air quality on the attendance of these two classes of swimming pools.

4. The outdoor swimming pool attendance variable, $P_O$, should be more strongly related to air quality. Specifically, we would predict a strong positive relationship between attendance at outdoor swimming pools and our low visibility variable. As in previous predictions, we would predict a strong positive relationship between the outdoor swimming pool variable and high temperature while the day variable should be inversely related for the same arguments.

5. The total swimming pool attendance, $P_T$, which is the sum of attendance at both indoor and outdoor swimming pools was regressed against the same variables. It provides a useful cross-check on the broad hypothesis about the effect of air quality variation. In this case, total outdoor swimming pool attendance, $P_T$, would be predicted to have a positive coefficient for the high temperature variable, and a negative coefficient for the day variable.

6. The sixth regression relates the number of visitors to the State Capitol in Salem, CV, to the same set of exogenous variables measured in Salem. On a priori grounds, visiting the State Capitol might be viewed as an indoor activity and, theoretically, might be treated as a substitute for alternative outdoor activities. This proposition is not advanced with confidence. It is possible that the activity represented by visiting the State Capitol might be independent of air quality for variation within some reasonable range. Nonetheless, we would predict that the coefficient for

low visibility in this regression should be negative, the temperature variable coefficient should be positive. The day variable offers something of a problem. It is not clear how this variable should be related to the number of Capitol visitors. Some visitors to the Capitol come in tours that are prearranged. The number of tours is not a function of day of the week. One might predict that the weekends would attract more families out for one-day family outings. On this basis alone, one would predict a positive relationship between the number of Capitol visitors and the day variable.

7. The City of Salem has three public swimming pools. They are all outdoor. Following the same arguments applied for Eugene, we predict a strong positive relationship between swimming pool attendance and low visibility, a positive relationship with high temperature, and an inverse relationship with day of the week.

Table III.2 offers the empirical results for the seven regressions outlined above. Regression coefficients significant at the .01 or .05 levels are indicated. All coefficients significant at levels higher than .05 are assumed to be zero. These empirical results can be summararized as follows:

1. Operating on a .05 level of significance, the data revealed that low visibility and attendance at Armitage State Park are apparently statistically independent. The regression coefficient is presumed to be zero. The high temperature variable is positive as predicted and statistically significant at the .01 level. The data suggest that attendance at the Armitage Park and day of the week are statistically independent. That is, the regression coefficient for day is assumed to be zero. Overall, the regression explained only 23% of the variation in attendance at Armitage. However, the F-statistic is significant at the .01 level suggesting that there is regression. However, the performance in this regression would suggest that there is a set of other variables that determine the overnight attendance at this particular state park.

2. The regression between the number of nine holes played at Green Acres Golf Course in Eugene and our set of independent variables also revealed that, on a statistical basis, low visibility - our index of air quality - is independent of this use of golf facilities. The regression coefficient here is assumed to be zero. However, the regression coefficients for high temperature and day are both positive as predicted and significant at the .01 level. Overall the regression explains 50% of total variation in G. The F statistic is significant at the .01 level.

3. In the case of indoor swimming pool attendance in Eugene, low visibility also reveals statistical independence. However, again, the high temperature and day variables reveal the predicted signs and are significant at the .01 level. Fifty-seven percent of total variation in $P_I$ is accounted for by the regression. The F statistic is again significant at the .01 level.

TABLE III. 2

Participation in or use of a Selected Set of Dependent Variables Against Visibility, Temperature and Day.

Regression Results: Salem and Eugene, Oregon, 1970

| Regression Number | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Dependent Variable: | A | G | $P_I$ | $P_O$ | $P_T$ | Cap. Vis. | P |
| Regression Coefficients, Etc. | | | | | | | |
| Constant | 17.8 | -.73 | -1197.30 | -2973.64 | -4228.56 | -258.8 | -2164. |
| Low Visibility | -.3 | .67 | 5.21 | $11.91^a$ | $18.11^b$ | -1.04 | $10.07^a$ |
| High Temperature | $.89^a$ | $1.07^a$ | $20.83^a$ | $43.71^a$ | $64.88^a$ | $7.62^a$ | $34.52^a$ |
| Day | 2.05 | $6.31^a$ | $-182.01^a$ | $-199.65^a$ | $-421.19^a$ | $64.59^b$ | $-206.50^a$ |
| $R^2$ | .23 | .5 | .57 | .74 | .66 | .20 | .74 |
| F-statistic | $7.50^a$ | $25.40^a$ | $22.39^a$ | $46.21^a$ | $31.65^a$ | $6.14^a$ | $48.40^a$ |
| Sample size | 78 | 78 | 54 | 54 | 54 | 78 | 55 |

Notes:

[a] Significant at the .01 level

[b] Significant at the .05 level

4. For attendance at outdoor swimming pools in Eugene, the low visibility variable reveals a much stronger influence. In this case, the regression coefficient is positive and significant at the .01 level. A priori considerations would have suggested this should have been the case. As in the previous regression, the high temperature and day variables revealed the predicted signs and are significant at the .01 level. Overall, 73% of total variation in $P_O$ is accounted for by the regression. The F statistic for this regression is also significant at the .01 level.

5. The regression for total pool attendance in Eugene produces comparable results to the regression on outdoor pool attendance. That is, the low visibility variable is positively related to total pool attendance and significant at the .05 level. The coefficients for high temperature and day both bear the predicted signs and are significant at the .01 level. Sixty-five percent of the total variation in $P_F$ has been accounted for by regression. The F-statistic is significant at the .01 level.

6. The regression relating number of visitors at the State Capitol to the set of independent arguments is the weakest of all seven regressions in terms of the amount of variation it accounts for. Low visibility is revealed as statistically independent to the number of visits to the capitol. The coefficient for this variable is assumed to be zero. Capitol visitations do appear to be related to temperature. The regression coefficient for high temperature bears the predicted positive sign and is significant at the .01 level. The coefficient for day is significant at the .05 level, is positive, and quite large. The interpretation of this is somewhat obscure. Only 20% of the total variation in capitol visitation is accounted for by regression. However, the F-statistic is significant at the .01 level.

7. In the case of pool attendance for Salem, the regression performance compares with the results for Eugene. That is, the coefficient for low visibility is positive and significant at the .01 level. This sign relationship is as predicted. For high temperature and day, the coefficients bear the predicted positive and negative signs respectively and they are significant at the .01 level. These variables and this regression account for 74% of the total variation in P. The F-statistic is significant at the .01 level.

What are the interpretations that one would apply to these seven regressions, particularly with respect to the impact of air quality variation? Clearly, the linear model has substantial power in accounting for variation in the respective dependent variables. This is evidenced by the consistent failure to refute hypotheses about lack of regression. All F-statistics were significant at the .01 level. But there is substantial variance in the amount of overall variation in the dependent variables that the regressions account for. The range in the amount of variance accounted for by regression extends for a high of 74% to a low of 20%. The high temperature and day variables also reveal themselves as powerful in explaining variation in the respective dependent variables.

What do these regressions suggest about the role of air quality variation in the determination of what people do? From the examination of the limited set of activities associated with the facilities examined in regression, the answer is unclear but there are suggestions of relationship.

Consider, first, the regressions for which low visibility proved statistically insignificant. These were the regressions for overnight attendance at Armitage State Park (A), the number of nine holes played at Green Acres Golf Course (G), the attendance at indoor swimming pools in Eugene ($P_I$), and the number of visitors to the state capital in Salem. In each of these cases, low visibility revealed itself as being statistically independent (i.e., having a zero relationship) of the respective independent variables. These results are probably plausible in terms of the underlying theory for this analysis.

The most difficult of these cases is probably the one of Armitage State Park. We attempted to treat overnight attendance at Armitage State Park as an outdoor "camping" activity identical to data that might apply to state parks located in more remote and specific camping areas. However, as indicated in the description of the independent variables, Armitage State Park is located on the McKenzie River and might be viewed as effectively in Eugene. It is also easily accessible from Interstate Highway I-5. These characteristics make the Armitage State Park facility attractive to tourists or to University of Oregon summer students who are looking for overnight camping facilities. The City of Eugene does attract tourist-visitors due to the number of lumber and plywood mills in the area that offer free tours and because of the location of the University of Oregon. Due to these circumstances, the Armitage State Park facility might theoretically be used like any other overnight camping facility and for reasons that are independent of the quality of the air, under conditions of normal air quality variation. Unfortunately, there are no other state, federal or Bureau of Land Management camping and park facilities in the area for which we have air quality data.

The regression for the golf variable, G, reveals a zero relationship between low visibility and this dependent variable. This is somewhat disconcerting. Playing the game of golf clearly involves an outdoor and recreation type activity. The game is played in the open atmosphere. Perception of the air quality component of the atmosphere should reasonably be influenced by visibility. Other factors involved in that perception would include atmospheric temperature, presence of rain, etc. In the regression for this golf variable, high temperature did reveal a very strong positive relationship. Why does the playing of golf appear to be unaffected by air quality as measured by low visibility? An explanatory hypothesis is not obvious and this study is not required to provide one. However, the anser to the question may be tied up in the character of the game itself and the type of people that play it.

The zero relationship between low visibility and attendance at Eugene indoor swimming pools is also difficult to explain. If deterioration in air quality does influence the set of activities that individuals enjoy, and if individuals have a choice of the type of facilities they might use in the face of air quality variation (such as indoor as opposed to outdoor swimming facilities), then one might expect (on theoretical grounds) that deterioration in air quality would lead them to substitute indoor for outdoor swimming facilities in the face of a reduction in air quality, other things equal. That is, we would predict an inverse relationship between the use of indoor swimming facilities and low visibility. However, the empirical results reported here suggest the relationship is neutral.

This does not refute the hypothesis being examined here. The most that the hypothesis about relationship suggested was a weak inequality (less than or equal to). If one were to find support for the strict inequality (less than), there would be stronger support for the hypothesis about substituting one activity for another under variation in air quality. When one is forced to accept the weak inequality, what remains is the uncertainty over the manner in which activity substitution takes place if, in fact, it does.

The case of the empirically suggested zero relationship between the number of visitors to the State Capitol and low visibility is less troublesome. The a priori considerations that lead to using the number of visitors to the State Capitol as a dependent variable were not rigorously derived. The argument was that the activity involved in visiting the State Capitol is a recreation-type activity (although, admittedly, it might also be viewed as educational) as well as indoor; therefore, one might predict an inverse relationship between air quality and State Capitol attendance. However, without other information, this relationship would be predicted as a weak inequality (i.e., less than or equal to). As it turned out, with the data employed in this analysis, the sign on the coefficient relating air quality to attendance at the State Capitol was negative. However, the coefficient was not significant at any level and hence the conclusion of no relationship. It may well be that the activity involved in visiting the State Capitol is more educational than recreational and, in that case, the role of air quality in affecting the demand for that type of facility may, in fact, be neutral. The regression for this dependent variable was conducted here primarily because of the availability of data and on the casual assessment that the activity involved in visiting the State Capitol may be more educational than recreational and, in that case, the role of air quality in affecting the demand for that type of facility may, in fact, be neutral.

The relationship between low visibility and attendance at the outdoor swimming pools in both Eugene and Salem were, again, positive and highly significant. These results might be regarded as "clean" in the sense that they bear the predicted sign and were highly significant. These results provide substantial presumptive and empirical support for the overall hypothesis that air quality makes a difference. The most important aspect of these results relates to the fact that the results are strong where we would predict they should be strong. A priori considerations suggested that swimming is definitely a recreation activity. Where the activity is undertaken in the out-of-doors and if air quality makes a difference, the results should be strong.

On an overall basis, there is enough supportive empirical evidence to suggest that air quality does make a difference and that consumers do engage in some kind of activity substitution under the variation of air quality. What is not clear is the character of the substitution and the welfare and economic costs associated with it. The answer to the latter question depends on both the magnitude of the marginal rates of substitution between activities affected positively by air quality and those that act as substitutes as well as on the technical or market commodity characteristics of the activities. The answer to the welfare question depends on the character of the activity set in the real world. That is, for analytical purposes we have assumed that consumption activities are divisible on a continuous scale and that the utility function is also continuous. If these conditions hold in practice, variation in any independent variable might lead to continuous reductions (increases) in one activity with corresponding changes in the associated market commodities and use of public facilities, as well as continuous increases (decreases) in the consumption of substitute activities with corresponding changes in associated market commodities and use of public facilities. In actual practice, the consumption activities we have reference to might be better measured on an integral scale. In this case, consumption activities would be produced and consumed in integral amounts. If this were the case, the consumer's problem might be better described as an integral programming problem in which case, variation could take place in the effective independent variables over some range without affecting the level of consumption of any optimal consumption activity set. Put otherwise, under these circumstances air quality might vary over a range of unknown width without affecting the precise consumption set or welfare.

## IV. ANALYSIS OF QUESTIONNAIRE DERIVED DATA

### Characteristics of Travelers

As indicated in Section 2 above, this research design involved interviewing a set of out-of-state parties traveling in Oregon for pleasure during the month of August, 1971. The questionnaire instrument provided in Appendix III was administered to 401 out-of-state parties. The questions and hypotheses which we were attempting to obtain insight to are outlined in Section 2 above. Before returning to those questions and hypotheses and the discussion of relevant data, it may be useful to outline some of the characteristics of the parties interviewed.

Fifty-four percent of all parties interviewed came from California; 20 percent came from the state of Washington. Of the remaining 26 percent of interviewed parties, 9 percent came from other western states while the residual was distributed over the rest of the nation and Canada.

In addition to home state, interviewed parties were asked for city of residence. Utilizing the 1970 census preliminary reports to establish city populations, the cities listed by respondents were coded into seven population categories with "less than 2500" at the lower end and "more than 500,000" at the upper end. Twenty-two percent of all respondents indicated residence in a city of more than 500,000 and twenty-three percent of the respondents listed residences in cities in the "2500 to 24,999" class. The remaining respondents were fairly evenly distributed in the other five population bands.

Several of the questions asked related to the activity plans of the vacationer prior to leaving home. The questions asked for plans relating to places they intended to visit, the number of days they intended to stay in Oregon, and the set of highways they intended to use in their travels. In terms of the places vacationers planned to visit in Oregon, eleven identifiable sets of places were established for coding purposes. Forty-one percent of all respondents indicated plans to visit the Willamette Valley cities. Other areas which respondents revealed as having high attractiveness included the coastal recreational areas for which 32 percent of respondents indicated plans to visit, the coastal cities which 25 percent of respondents indicated plans to visit, and the city of Portland, which 23 percent of respondents indicated plans to visit. Interestingly, only 8 percent of respondents indicated plans to visit Willamette Valley recreational areas. These percentages summed to more than 100 percent due to the opportunity for listing more than one area in the set of planned areas. One suggestion obtained from these data is that, if the population interviewed in this study reflects the characteristics of the population of all parties traveling in Oregon for pleasure (even in the summer), the great bulk of these travelers do not depart significantly from the main traffic arteries.

The same observation applies when one considers the set of highways that these travelers planned to use to their destination and in leaving the state. Sixty-six percent of all parties planned to use Highway I-5 to their destination. Forty-three percent indicated plans to use Highway 101 to their destination. The percentages of responses for other highways are considerably smaller. These data are provided in Appendix IV.

Thinking in terms of pre-vacation plans, respondents were asked the degree to which they intended to engage in nine specific outdoor activities readily available to Oregon tourists. This set of activities included camping, boating or water skiing, golfing, ocean beach activities, hiking or walking, swimming, pleasure driving and sightseeing, salmon fishing, and trout fishing. To each of these activities respondents were asked whether they planned to engage in the activity a lot, quite a bit, a little, none, or "don't know".

An analysis of the data generated by these questions revealed some interesting results. For the activities camping, boating or water skiing, golfing, salmon fishing, and trout fishing, more than 75 percent of the respondents in each case said that they did not plan to engage in these activities. This is superficially interesting in the sense that these activities reflect several of the activities that are presumed to be prime attractions for summer tourists. The response configuration to this set of questions may in part be reflected by the sample frame. However, there are no *a priori* reasons to presume that the sample frame was biased against these activities.

In response to the question regarding the planned use of time in the activity called "pleasure driving and sightseeing", 51 percent of the respondents indicated "a lot" while 23 percent indicated they planned to engage in this activity "quite a bit". The activities ocean beach activities, hiking and walking, and swimming received the responses "a little" 24, 50, and 25 percent respectively.

These questions on the planned use of time in specific outdoor activities along with the responses relating to planned uses of highways and the planned areas of visitation seem to suggest that the out-of-state tourist who is reflected by the sample frame used in this study is very markedly "tracked" in terms of the path that he travels and the activities that he engages in. This observation is supported by additional data to be cited below. The full data configuration describing responses to the planned activity questions are provided in Appendix IV.

Other interesting characteristics of the set of travelers sampled relate to years of education completed, age of respondent, and sex. Regarding education, approximately 37 percent of the respondents had completed college, 25 percent had partial completion of college, 35 percent indicated a high school education, while approximately 3 percent listed grade school or no school as highest educational achievement.

Regarding the age characteristics of respondents, the age bands that respondents were offered to associate with were five in total. These included the 20-29, 30-39, 40-49, 50-59, and 60 and above brackets. The age distribution of respondents was quite symmetrical. Fourteen percent of the respondents fell in the 20-29 bracket, 21 percent fell in the 30-39, 25 percent fell in the 40-49 bracket, 22 percent fell in the 50-59 bracket, and 17 percent fell in the 60 and above.

The sex distribution of the respondents is also interesting. Of the 401 total respondents, 61 percent were male and 39 were female. Interviewers were under instruction to attempt to balance the sex distribution of respondents if possible. Since only 5 percent of all respondents indicated their party size as one (1), there is reason to presume that there may have been a choice available to interviewers in terms of the sex of respondent. The actual sex distribution of respondents seems to suggest that either the interviewers interjected some bias or the parties themselves revealed some process by which sex made a difference in terms of which party member should respond to the request of an interviewer. The precise reason for the uneven sex distribution of respondents is not important for purposes of this study.

## Characteristics of Parties Changing Plans

Two of the questions of this study set out to provide insight to questions related to whether vacation travelers actually did change their plans en route due to variation in the parameters of their planning frame and whether, for those who did change plans, air pollution could account for any of those changes. Each of the parties interviewed was asked the question "have your vacation plans for Oregon changed since you arrived in the state?" Of the 401 respondents, 59 said that they have changed plans in the state while 340 said there have been no changes and two responded they did not know or did not answer. The 59 parties who indicated a change in plans while traveling in Oregon were offered a list of factors that may have influenced the plan changes they experienced. The reasons included rain, heat, crowded facilities, air pollution, lack of money, automobile breakdown or accident, sickness in the family, and "other". Those that indicated "other" were asked to specify what this meant. There were 30 affirmative responses in the "other" category. When the 30 questionnaires with this response were examined, it turned out that, where explanations were offered, most comments spoke to the crowded facilities and lack of available rooms. The second highest affirmative response related to rain; there were 15 responses in this category. Crowded facilities showed 11 affirmative responses. Of the 59 parties who indicated a change of plans, only 6 indicated that air pollution had anything to do with their behavior.

The parties that did change plans were also asked if, for reasons other than air pollution, their change of plans had affected their planned expenditures. That is, they were asked whether planned spending had increased, decreased, or remained the same; a fourth response of "don't know or no answer" was also provided. Of the 59 respondents who changed plans, 22 indicated their spending had increased, 13 indicated their spending had decreased while the residual indicated no difference or they did not know. The distribution of the estimates of increased expenditures required by vacation plans is fairly even with a median of about $100 increase. The distribution of estimated reductions in spending resulting from vacation plan changes is more skewed with a median and mode in the $51-100 range.

These data seemed to add further support to the observation that out-of-state parties traveling in Oregon for pleasure have fairly fixed plans about the path of their travels and the amount they will spend. Where information or events require parties to alter their plans, the factors requiring changes may lead the parties to increase their spending over their expectations slightly but, given that some parties have their planned expenditures reduced by factors affecting their vacation plans, the net impact of vacation plan changes on spending in the state may be approximately zero. The data from this sample should not be advanced as strong evidence of other conclusions.

## THE IMPACT OF AIR POLLUTION

The primary purpose for administering the interview instrument was to obtain insight into the question of whether air pollution actually led vacationers or consumers of outdoor and recreation-type activities to alter their plans, spending, and behavior. The questionnaire design also permitted the generation of perceptions of the air quality situation in Oregon and to obtain evaluations of comparative air pollution between areas visited in Oregon and home areas.

For purposes of this analysis, the answer to the impact question can be approached from two directions. First, of the 59 parties that indicated their vacation plans had changed, only 6 indicated that air pollution had any bearing on their behavior. These 6 responses constituted only 1.5 percent of the total responses and cannot be viewed as statistically significant in relation to any of the hypotheses of interest to this study.

While the number of those who changed plans and revealed air pollution as a factor in this change was small, the observations of respondents in this category are of interest. The six respondents that indicated air pollution did make a difference in their vacation plans were asked probing questions about what kind of air pollution affected their behavior and in what ways. The responses along with some descriptive information about the respondents are provided below:

a. A male truck driver from California, in the age bracket 40-49 said: The field burning and smoke from Salem and Eugene affected our plans. We were thinking of staying over in Eugene, but we didn't because of the smoke. We just wanted to get away from it and go somewhere where there isn't any smoke. For one thing, you can't see the scenery, and the smoke bothers my sinus. There is a lack of good, fresh air.

b. A television repair shop owner from California, in the age bracket 40-49 said: Portland smog is bad because of industrial and auto pollution. We skipped a day in Portland and went to Vancouver instead.

c. The wife of a California salesman, in the age bracket 50-59 said: We were astonished at the sawdust burners used by the mills, like near Roseburg. We were going to stay in Eugene, but the sawdust burners in the area made us decide to come on up north. It was a haze we didn't expect.

d. A male lawyer from California, in the age bracket 20-29 said: Basically it is the countryside pollution or haze one sees from the highway that bothered me. I feel it is worse than in California. We shortened our stay due to the pollution. We had some idea of moving to Oregon, but we're not too sold on Oregon.

e. The wife of an Agricultural Inspector from California, in the age bracket 50-59 said: (Didn't specify kind of air pollution) We had planned to stay overnight in Portland; but because of air pollution, we decided to go on east to The Dalles.

f. A male Steamfitter from California, in the age bracket 50-59 said: The smog in Southern Oregon is bad, all the way up the Willamette Valley as far as Salem. Didn't travel any farther north, but I'm sure Portland would have been worse. I don't like smog. If there is going to be smog, a person might as well go elsewhere.

Several observations about these comments are required. First, all respondents were from the state of California. All the comments seemed to indicate a set of preconceptions about the relative air pollution in Oregon vis-a-vis their home state of California. For this sub-population, experience seemed to indicate that the relative difference in air pollution did not meet their expectations.

Another observation about the set relates to the qualitative character of the pollution observed. They speak of field burning, sawdust burner smoke, and "countryside pollution". One party observed the bad "Portland smog". The interesting thing about these observations is, not that they differ from observations generated by Oregon citizens, but rather they are so much like comments coming from within the state by residents and that there were so few respondents who indicated air pollution affected their behavior.

The question about whether air pollution in the state was statistically related to the change of vacation plans by travelers was tested in a multivariate analysis of variance technique. This analysis will be discussed below. For present purposes, we will continue with the more descriptive material relating to perceptions of the relative air pollution in Oregon vis-a-vis home area.

The questionnaire contains five questions having to do with perceptions of relative air pollution in Oregon and about the qualitative character of the Oregon problem. Analysis of the data from these questions suggest something about why so few people revealed air pollution as having affected their plans and just how serious an air pollution problem they think Oregon has.

Of the 401 total respondents, only 76 (19 percent) responded that the Oregon problem was "quite" or "very" serious. One hundred eighty-one respondents indicated the problem was "not too" serious and 136 indicated there was "no problem". Eight respondents indicated they did not know.

In a similar question asking about how serious the air pollution problem is in their home area, 223 respondents (57 percent) indicated that the problem was either quite or very serious, while 12 said it was "not too" serious and 64 indicated there was "no problem". Responses to these two questions suggest that, in terms of perceptions, it is relative rather than absolute air pollution that makes a difference.

This is suggested further by another question that asked about perceptions of relative air pollution in Oregon vis-a-vis their home area. Two hundred forty-five respondents (61 percent of the total) indicated that Oregon had less air pollution than their home area. Seventy-one respondents indicated Oregon had more pollution while 63 indicated it was about the same. An interesting sub-set of the responses to this question were coded "qualified less in Oregon". Respondents who observed either more or less air pollution in Oregon vis-a-vis their home area were asked to explain observations. The verbal comments are provided in Appendix IV, however, it is interesting to note that, for those who provided a qualified "less in Oregon" spoke quite specifically about the extensive field burning smoke problem in the Willamette Valley.

Review of the verbal comments provided in Appendix IV and relating to perceptions of relative air pollution reveals an almost unanimous agreement on the distastefulness of field burning smoke. Comments included the observation that "the fire on the farms is quite bad" or that they had observed "a heavy and obnoxious smoke". One respondent indicated that, in terms of a statewide comparison, Oregon had a much smaller air pollution problem than the home state of California but "where there is field burning, the problem is much greater".

## MULTIVARIATE A.N.O.V.

In all, the interview instrument had 47 questions for which the responses could be listed as "closed ended". Most of the data from this set of questions were in code form. These codes related to such matters as size of city, state of origin, planned expenditure categories, qualitative perception of air pollution, level of education, age, etc. In only three cases were absolute numbers requested as estimates or statements of particular values. These pertain to the estimated amount of planned expenditures to be made in the state of Oregon, the number of days they planned to spend in the state, and the size of the total party.

The data from this subset of questions in the interview instrument might have been statistically processed in a number of ways. After observing the very weak case to be made for air pollution in affecting the travel plans and behavior of tourists traveling in Oregon for pleasure as evidenced by the fact that only 6 parties indicated air pollution made a difference, it was decided to slice and analyze the data along two lines that may provide insights into the character of the population being examined and to the reasons for their behavior. The points of data partition were:

1. At question 17 which asked whether vacation plans for Oregon had changed since arriving in the state; the partition at this point was between those who had changed and those who had not or did not know.

2. At question 25, which asked the perception of respondents toward the seriousness of Oregon air pollution; the data were partitioned between those who responded "quite serious" and "very serious" on the one hand and those who viewed it as "not too serious", "not serious at all" or did not know on the other.

These data partitions made sense on several grounds. The question dealing with the change in vacation plans was included to assist in finding out whether the population in question is sensitive to unanticipated information received in the course of travel and sensitive in the sense that parties changed their behavior. The question on perception of Oregon air pollution provided a meaningful point of partition because the focus of this research is on the impact of air pollution on behavior and, since air pollution revealed itself as having no apparent impact on the in-trip plans and behavior of travelers, it seemed to make sense to focus on the question of whether there are meaningful differences between the set of travelers that view the pollution problem in Oregon as either quite or very serious as opposed to those who saw the problem in Oregon as of more or less minor concern. The latter partition would permit a continued focus on the impact of air pollution, although not in quite the same way as was anticipated at the outset.

With the partitioning of the data set along the lines outlined here in mind, it was decided to subject the data for a selected set of variables to analysis through the multivariate analysis of variance (MANOV) technique.[1] As used in this research, MANOV technique was used to examine hypotheses about equality in means of variables generated by two groups. For purposes of this research, the hypotheses in question at this juncture were:

1. The subset of respondents who changed vacation plans while in Oregon and the subset of respondents that did not change vacation plans were drawn from the same population.

2. The subset of respondents who indicated that air pollution in Oregon is either a "quite" or a "very" serious problem and a subset that perceived no problem or not too serious a problem were drawn from the same population.

The computer program used in performing this analysis was constrained to a set of 20 independent variables. To accomodate this constraint, a set of variables that included state of origin, a set of 10 planned outdoor activities, planned expenditures in Oregon, the question regarding spending changes, perception of pollution at home, relative air pollution in Oregon, party size, highest education achieved, occupation of major bread winner, age, and sex was utilized. This same set of 20 variables was used to attempt to predict those respondents who did change their vacation plans in Oregon versus those who did not change plans en route on the one hand and to predict those that viewed air pollution in Oregon as relatively bad versus those that viewed it as not so bad on the other. A separate "interaction" analysis was performed which attempted to discover a systematic relationship between those respondents who saw pollution as "bad" in Oregon and changed plans while traveling in the state on the one hand and those who did not view pollution as "bad" and did not change plans while traveling in the state on the other. The MANOV technique provides tests for hypotheses relying on assumptions about linear statistical relationships. The major test statistic is the F statistic which is used for examining hypotheses about linear fit. The computer program used in this research also generates a computed discriminant function the use of which provides a way of comparing vectors of mean values from two populations and for assessing the relative importance of the contribution of each in dependent variable involved in developing the computed value of a particular test statistic.

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[1] For one discussion of the use of multivariate analysis of variance in testing hypotheses about means, see Donald F. Morrison, Multivariate Statistical Methods, McGraw-Hill Book Company, New York, 1967, Chapter 4.

## Change Vs. No Change

In the attempt to predict respondents who changed plans as opposed to those who did not from the set of 20 variables outlined above, the analysis was not particularly clear. The computed F value with 20 and 380 d.f. was 1.686. The critical value of F at the 5% level was 1.60. The fact that the computed F only marginally exceeded the critical value of F left serious questions as to whether the results were really statistically significant.

In the first computer run, the discriminant function revealed a subset of 10 independent variables that appeared to be most influential in predicting the changers vs. the non-changers. The variables along with the discriminant function coefficients were:

| | | |
|---|---|---|
| 1. | camping | + .015 |
| 2. | boating | - .020 |
| 3. | golfing | - .021 |
| 4. | ocean beach activity | + .011 |
| 5. | salmon fishing | + .011 |
| 6. | trout fishing | + .018 |
| 7. | change of spending variable | - .034 |
| 8. | highest education | + .014 |
| 9. | occupation | + .012 |
| 10. | sex | + .027 |

Before commenting on the implications of the discriminant function analysis, it should be pointed out that the signs on the discriminant function coefficients are not to be viewed like the signs on regression function coefficients. The discriminant function coefficients do not provide similar qualitative information about relationship.

Precise interpretation of the ten variables shown above that discriminate in the comparison of means between the set of respondents who changed travel plans en route and those that did not is not clear. However, six of the strictly outdoor "planned activity" variables emerged. Also, the sex, occupation, and education variables emerge as important and, along with the important planned activity variables suggest an outline of a behavior model.

Since the F analysis revealed a "fit" that was at least marginally significant, it was decided to rerun the analysis of variance problem using the subset of 10 variables listed above as the set of independent variables in an effort to obtain an improvement in "fit" and to examine whether this might change the size of the discriminant function coefficients.

The second run did increase the sizes of most discriminant coefficients. More important, however, the computed value of F at 9 and 391 d.f. was 1.94. The critical value of F at the 5% level is 1.90. Under the model employed in this analysis, the data do not allow us to reject the hypothesis of equality of means. There is no suggestion that the respondents who change vacation plans are, in fact, from a different population than those who do not.

## Pollution Bad Vs. Not So Bad

The same original set of 20 independent variables were used in an effort to predict those respondents who viewed pollution as quite or very serious in Oregon as opposed to those who viewed it as a less serious problem. In this case, the MANOV test for equality of means provided some statistically interesting results. The computed F value at 20 and 380 d.f. was 2.26 while the critical F at the 1 percent level was 1.92. The fit is particularly good. The conclusion is that there is a difference in mean values. The suggested implication is that the set of respondents who view pollution in Oregon as a serious problem comes from a different population than the set that view pollution as not too serious.

The computed discriminant function reveals five variables that seem more influential in accounting for this behavior difference. These are:

| | | |
|---|---|---|
| 1. | golfing | + .021 |
| 2. | hiking & walking | - .010 |
| 3. | pleasure driving & sightseeing | + .029 |
| 4. | trout fishing | + .012 |
| 5. | education | - .032 |

In this attempt to discriminate between respondents that view pollution in Oregon as bad as opposed to those who view it as not so bad, the five most influential variables turn out to include four "planned activity" variables and one relating to personal characteristic. These five variables do not readily reveal a model for differentiating between the two possible populations suggested here.

It is interesting to note that the variables for "pollution at home" and "relative air pollution in Oregon" were not revealed as particularly influencial in the discriminant function analysis. This is consistant with comments derived from the open-ended questions relating to air pollution that suggest it is relative air pollution that is important.

As in the analysis of the change vs. non-change data, the pollution bad vs. not so bad problem was rerun using the subset of 5 variables listed above as the independent variables. On the second run, the computed F value with 5 and 395 d.f. was 7.40. The critical F value at the 1 percent level is 3.06. These results are highly significant and require rejection of the hypothesis of equality of means. They also suggest something about differences in the populations of respondents.

## Interaction

As suggested above, an "interaction" analysis was performed in which we attempted to discover a systematic relationship between those travelers who changed travel plans and saw pollution as bad in Oregon on the one hand and those who did not change plans and did not view pollution in Oregon as bad. This analysis revealed a very poor fit. The computed F value was 1.22 with 20 and 380 d.f. while the critical value of F at the 5 percent level was 1.60. The hypothesis of equal means must be accepted. There is no evidence of systematic difference provided by these data.

## Data Analysis Extension

For purposes of this research, it made sense to partition the data along the lines provided by the "change in vacation plans" question and the question relating to perceived air pollution in Oregon. Upon completion of this data analysis, another data partition was suggested. That is, the question was raised of whether the location of interview site made a difference in data configuration. To respond to this question, the data were partitioned between those respondents interviewed in the Willamette Valley and those interviewed outside the Valley. The MANOV analysis performed on a data partition based on the geography of interview site provided some interesting results.

The data set was partitioned by geography at interview site and subjected to the multivariate analysis of variance technique. A broad comparison was made between Willamette Valley respondents and "outside" respondents. This analysis produced very significant results. This analysis required rejection of the hypothesis of equal means in the independent variables and, in effect, suggested that the set of respondents interviewed in the Willamette Valley came from a different population than the set interviewed outside the Valley.

The discriminant function analysis revealed a set of seven variables as contributing importantly in the comparison. This set included the planned activities of camping, golfing, ocean beach activities, hiking and walking, swimming, and pleasure driving. In addition, the variable reflecting perceived pollution in Oregon emerged as a strong variable. More close examination of the data on these seven geographic specific variables provided one interesting fact. Twenty-five (25) percent of respondents interviewed in the Willamette Valley observed that Oregon had either a "very" or "quite" serious air pollution problem. Thirteen percent of respondents interviewed outside the Valley made the same observation. The interpretive conclusion from this is not profound. The implication is that, if one asks people about their perceptions of air pollution and the question is asked while the respondents are in a so-called pollution zone, people will comment about the pollution. More importantly, however, the mere tendency of observing pollution is apparently not enough to require people to change their behavior.

Subsequent analyses comparing respondents in the Willamette Valley who viewed pollution as bad as opposed to those interviewed outside the Valley who viewed pollution as bad as well as the corresponding comparison of respondents who viewed pollution as less severe both interviewed in the Valley and out, produced significant differences in mean values of independent variables. The discriminant function analysis also suggested that the observed differences in mean values could be accounted for by differences in the set of activities vacationers planned to engage in, their comparison of air pollution in Oregon as opposed to their home area, education, age and sex respondents. One inferential interpretation of this analysis relates to the explanation of the variable configuration suggested by discriminant function analysis.

In all the comparisons made thus far and for those that produced conclusions of significant difference in mean values of independent variables, a number of the so-called planned activity variables continued to emerge as apparently important in explaining the differences observed. This data analysis that makes comparisons premised on a data partition specified by geography of interview site may suggest that the respondents may not be really different in terms of tastes and preferences but, rather, that the location of interview site influences the weighting that respondents provide to questions about planned activities. That is, we have observed through responses provided to other questions that the party visiting Oregon usually makes a "loop" through the state. That is, they will utilize different highways into the state than they will out of the state. Their path may provide them an opportunity to experience or brush close to activities as extreme as ocean beach activities on the one hand and camping in the high Cascades on the other. If the interview process "catches" a party on the Oregon coast where there is ample opportunity to observe and enjoy ocean beach activities or salmon fishing, it seems likely that their responses to questions in these areas would provide more weight to these activities. Other illustrations could be provided. The point of this is to suggest that the site of interview may substantially affect the data configurations that we are observing for the set of planned activity variables.

## V. SUMMARY AND CONCLUSIONS

The primary motivational factor influencing the funding of this broad project on the economic effects of air pollution was a recognition that measuring the economic magnitude of the presumed effects of air pollution was very difficult. Previous research on the measurement of air pollution impacts had not reduced interest in this question.

This portion of the Oregon State University project has relied heavily on the theoretical implications of a model that attempted to tie air quality (or other perceived environmental factors) to the set of activities that individuals and households consume. The underlying thesis of the research has been subsumed in the joint propositions that (1) if air pollution really does make a difference to individuals, one should be able to observe variation in the kind of activities people consume as a result of variation in air quality and, (2) if the activity consumption set does change as a result of changing air quality, one should theoretically be able to observe the market consequences of that changed behavior. As a theoretical corollary one should be able to estimate the dollar cost to the individual and to society induced by changing air quality. The empirical methodology for approaching these propositions proceeded along two main lines.

The regression analysis discussed in Section III was intended to examine the first of the above propositions. Those regressions constituted attempts to discern qualitative relationships between visibility (our proxy for air quality) and attendance at a selected set of recreation related facilities. Again, the purpose here was to establish an empirical tie between a set of arbitrarily specified outdoor related public facilities and air quality. The regressions were not intended to provide estimates of the concentration of pollution per se.

The second proposition outlined above was approached through an empirical method that involved the study of a set of out-of-state visitors to Oregon for pleasure during August 1971. This procedure extends from the fact that both the extent and the quality of air pollution in Oregon varies. Nonetheless, both residents and non-residents alike acclaim the great bulk of the Oregon environment as reflecting something of an environmentally pure environment. Many non-residents visit the state each year to participate in activities that utilize the environment.

Given that the Willamette Valley reveals rather marked seasonal air pollution during the summer months as a result of field burning and that this burning occurs at a time overlapping with the peak tourist flow, it made sense to attempt to test the broad hypothesis about the effect of air pollution on consumer behavior by studying the behavior of out-of-state tourists traveling in Oregon for pleasure during the summer months and trying to relate this to air quality.

The results of the analysis of survey data do not support either the main theoretical hypothesis predicting that deterioration of air quality would lead consumers of outdoor activities to alter their behavior or the preconceptions that seem to prevail about the effects of air quality. Of the 401 parties interviewed in this study while traveling in Oregon for pleasure, 56 apparently encountered parameter changes of sufficient magnitude to warrant changing their vacation plans en route. Of the 56, only 6 parties indicated that air pollution had anything to do with their behavior. These 6 responses cannot be viewed as significant in any statistical sense of the word.

The power of preconception in structuring one's thinking is strong. In terms of the objectives of this research, the statistical results cited here on the effects of air pollution on the behavior of tourists is negative. One's initial reaction is to look for mitigating circumstances. Are there reasons that would account for our inability to observe the anticipated statistical relationship between air quality and tourist behavior? The answer to this could be "yes" and the explanation may lie in both the condition of the Oregon atmosphere during the interview period and the character of the sample population.

Regarding the atmospheric conditions prevalent in Oregon during the interview period, it is possible that the period was relatively pollution free. This research has suggested at several points that primary source of air pollution during the summer months in the Willamette Valley is the smoke produced by burning grass seed fields. Automobile exhaust and the smoke from saw, pulp, and planing mill operations also contribute significantly on a regional basis. The relevant unanswered question for this research relates to the condition of the atmosphere over the period August 19 through August 31, 1971. That is, is there reason to believe that the interviewing period was characterized by relatively clean atmospheric conditions and hence provided tourists, at least in the Willamette Valley, with relatively low values of any pollution index they might compute.

In an attempt to provide partial answer to this question, we have examined U.S. Weather Bureau data relating to the relevant atmospheric conditions and taken at the airports at Salem and Eugene over the relevant span in August, 1971. In Table I below, we have provided data on low visibility by day and city embellished with editorial observations made by weather bureau observers on occasion. For purposes of this array, low visibility data are taken from the daylight hours of 0700 through 1900 in order to provide reasonable simulation of the environmental backdrop observed by travelers in the Willamette Valley area in the period in question.

Examination of the visibility data and weather observer comments from the Salem and Eugene airports reveals that the interview period was marked by numerous days in which smoke and/or rain obscured the visibility in the Willamette Valley. Comments about the existence of fires and smoke are more prevalent from the Eugene station. We should note that the qualitative content of the editorial remarks may be a function of variance in weather station personnel or local procedure. Another point of observation, the 'low visibility' data for Eugene appear higher than the data for Salem on the average. This might be accounted for by a difference in the availability and distance of usable distance markers in the relevant sectors surrounding the airports. On the average, visibility in Eugene is probably lower than it is in Salem. In addition to the smoke from field fires, Eugene

## TABLE IV-1
## Low Visibility and Observer Comments Taken at Salem and Eugene, Oregon, Airports August 19-31, 1971*

| SALEM | | | EUGENE | |
|---|---|---|---|---|
| Date | Low Visibility | Comment | Low Visibility | Comment |
| 8-19 | 10 | K 50-◑ | 10 | fires N&S K lyer |
| 8-20 | 6 | RW; | 25 | fires NW-NE vsby NE ½K |
| 8-21 | 7 | R;Fk Ese-S | 15 | fires 1156-1856 RW; K |
| 8-22 | 10 | RW; | 10 | RW; |
| 8-23 | 15 | Vsby SE 3 | 12 | SE S Smky |
| 8-24 | 10 | | 15 | Fires W&N 1156-1356; Vsby Lwr NE & SE K |
| 8-25 | 5 | K; K20-⊕ | 3 | K |
| 8-26 | 8 | K layer; smky | 10 | Fires N 0956-1055 |
| 8-27 | 10 | RW; Smky | 7 | RW |
| 8-28 | 4 | K | 3 | FK |
| 8-29 | 20 | | 25 | |
| 8-30 | 3 | K; RW | 10 | R |
| 8-31 | 10 | RW | 10 | RW |

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* Explanation of Meteorological terms and abbreviations

Abbreviations - in remarks and visibility columns:
⊕ - overcast, i.e., 10/10 sky cover
◑ - broken, i.e., 5/10 to 9/10 sky cover

R - moderate rain.
RW - moderate rain showers.
K - smoke.
F - fog.

Shortened spellings:
VSBY - visibility.
SMKY - smokey.
LWR - lower.
LYR - layer.

Visibility - given in statute miles and fractions of miles. The visibility given in a weather observation is defined as "Prevailing visibility" and is the highest visibility which can be maintained throughout at least half of the horizon.

Source: U.S. Weather Bureau

is plagued with considerable airborne effluents from pulp, planing, and plywood mills. Again, the data from Table 1 suggests that visitors to the central Willamette Valley during the interview period were confronted with obscured visibility. This was primarily accounted for by the smoke from field burning fires and from background pollution provided by industry and autos.

Given that there was a prevalence of obscured visibility during the interview period, our attention is drawn to the question of whether the sample population reveals characteristics that might help account for the relative failure of respondents to be affected by the pollution they encountered. As indicated above and in Appendix IV, 54 percent of all respondents indicated California as their home state, 20 percent were from Washington, with the balance distributed over the rest of the nation relatively evenly. Perhaps more important, 68 percent of all respondents indicated living in cities with populations in excess of 25,000. Fifty-six percent indicated living in cities in excess of 50,000 population. Assuming that there is a positive relation between home city size and airborne pollution experience, one might expect the bulk of the sample to have been exposed to heavier amounts of air pollution in their home areas.

One could make an even stronger assumption about the experience respondents have had with air pollution. For example, one could assume that the California visitors on the average and the visitors from metropolitan areas in other states reside in areas where pollution is markedly worse than in Oregon. The questionnaire data provides some support to this hypothesis. For example, in response to Question 26 which asked about the relative seriousness of the air pollution problem in their home area, 55 percent of all respondents indicated either "quite" or "very" serious. Twenty-eight percent indicated "not too" serious a problem. Question 27 of the interview instrument asked about the relevant air pollution between Oregon and the home area. Sixty-one percent of all respondents indicated there was less pollution in Oregon, 15 percent indicated it was a problem of equal magnitude, while only 18 percent indicated Oregon had more pollution than their home area. These data, along with interpretations derived from the qualitative content of verbal responses to the pollution questions, indicate that, regardless of the amounts of smoke prevailing in the Oregon atmosphere and the absolute minimums on horizontal visibility, visitors included in the sample found less pollution in Oregon than they had observed in their home area.

One can conceive a behavioral model in which there are parameters reflecting tastes and expectations. If one views the model as representing an optimization problem and one that is being optimized through a linear or non-linear programming technique, it is possible for these parameters in the system to change over some small range without producing changes in behavior. It is possible that the threshhold values of the parameters--i.e., those values of the parameters which, if reached, produce a change in behavior--are established on the basis of experience in the home area. For those system parameters that are affected by atmospheric quality and for visitors that find the atmosphere in Oregon "cleaner" than the home areas, one might expect the parameters of the relevant behaviorial systems to move, but not by enough to reach the threshholds requiring behavioral change.

In terms of the hypotheses about the effects of air pollution that this research set out to examine, the conclusions must be viewed as negative. In terms of scientific investigation, negative conclusions are not viewed as disappointing per se.

In spite of the results of this analysis, this writer maintains the prejudice that there are social costs associated with air pollution. If this prejudice is in fact true, the question remains of how to measure those costs. The negative results produced here may provide a suggested direction. This research accepted on an a priori basis the proposition that the set of all consumption activities could be partitioned between those that conspicuously utilize the environment and those that do not. It may well be that the experience of most Americans has suggested that air pollution is more or less pervasive (i.e., as a parameter) and that they select among available recreation activities as if air quality was constant. There is discretion in the choice of recreation activities and what we observe is the product of preference, income, and time constraint comparisons. There is another class of "consumption activity" over which most individuals view they have less discretion. These activities evolve around the protection and maintenance of personal health. Perhaps individuals view the decision to assume a given amount of debt from a medical practitioner differently than they do in assuming similar amounts to other recreation type activities. That is, health may be viewed as a constraint. When one observes symptoms of deteriorating health, those symptoms are responded to and it makes no particular difference what factors gave rise to the symptoms. If, in fact, air pollution does affect the body functioning but individuals have no way of continuously monitoring the impact of that pollution, and their sole source of monitoring relies on their perception of symptomatic disease, then it would be very difficult for social scientists to observe a systematic relationship between air pollution and the behavior of people. Nonetheless, the behavior of people would be related implicitly to air pollution. The point is, it may be more fruitful to focus consumer oriented air pollution impact studies on the relationship between air pollution and disease than trying to observe regular and continuous variation in behavior resulting from air pollution and trying to measure the economic impact of those behavioral changes.

## VI. POSTSCRIPT

To repeat the conclusion expressed above, as far as this research has gone, air pollution has not revealed itself as particularly influential in affecting the set of consumption activities that consumers enjoy. This conclusion extends from the analysis of both the regression analysis and the analysis of questionnaire-derived data.

From the outset of this research, one of the innovations that this author contended to offer to this research on the impact of air pollution was the manner in which pollution was treated in the theoretical model relating air pollution to consumer behavior. Pollution was regarded to affect tastes for various classes of consumption activities and, hence, served as a shift parameter that could shift the relevant demand curves to the right or left, depending upon direction of change of pollution and the class of activity.

The empirical models employed in this research have been defended on more than one occasion as "reasonable" on both theoretical and empirical grounds. This assertion still applies; however, a footnote is required.

In both the regression and the MANOV analyses outlined above we have, in effect, been attempting to relate variation in air quality with certain predicted directional changes in the consumption level of various classes of activities. In terms of traditional economic jargon, we have been trying to observe the logical analogs to traditional substitution and income effects in the analysis of demand curves. It should be pointed out, however, the analysis of substitution and income effects takes place in a framework in which tastes and preferences are assumed constant.

After reading a draft version of the above material, my friend, colleague, and co-author on some materials, R. Charles Vars, observed that it was inappropriate to set up an empirical research model designed to examine traditional relationships such as is provided by the substitution and income effects of demand curves when, by hypothesis, we were going to allow tastes and preferences to vary as a function of air pollution. What difference does this observation make?

The importance of this observation relates to the problem of measuring the magnitude of economic impacts of air pollution on consumer behavior even if those impacts exist. Air pollution has been treated here as a shift parameter. That is, air pollution is treated much like income in the traditional analysis of demand curves. A change in this parameter should theoretically result in a lateral shift of the demand curves for several classes of activities. For those classes of demand curves affected by variation in the pollution parameter, we are saying that consumers would "consume" more or less of the activity (depending upon class of activity) at any given "price". This is a statement having qualitative content only. The regression and MANOV analyses performed above were designed to discover empirical support for this proposition. This empirical work was not intended to provide quantitative estimates of the cost to consumers of switching between consumption activities as a result of variation in air quality -- even if the analysis had provided strong evidence of switching.

If one wanted to estimate the dollar cost of the impact of air pollution on consumer behavior, he would essentially be committed to an argument in which the gross cost of air pollution to an individual consumer would be viewed as the sum total of the air pollution-related cost changes associated with the consumption of the relevant separate consumtion activities. The separate cost changes associated with each consumption activity affected would be computed, in terms of the usual theory, as the dollar cost of the sum of the income and substitution effects that result from varying the pollution parameter in the system. This is what Professor Vars' observation was about.

Even if there were data available to estimate the dollar cost to consumers of the pollution model counterpart to income effects, there is still the problem of estimating the dollar cost associated with the pollution model analogs to the substitution effects. Given the character of the model in which pollution is viewed as shifting the relevant demand curves, there is, by implication, no opportunity to estimate the sizes of those substitution effects. This last problem is complicated, according to the empirical observations outlined above, by the apparent absence of a continuous relationship between the pollution parameter and the set of consumption activities. Given the character of pollution variation and the character of the data set on the purchase and use of inputs to the consumption set, it is apparently not practical to observe or estimate the magnitudes of the relevant substitution effects. The corollary to this proposition is that coming up with meaningful estimates of the cost of air pollution to consumers may not be practicable. This is a substantive conclusion. Its importance should not be minimized.

# APPENDIX 1

## The Effects of Changes in Air Quality on Tourist-Related Industries in a Region

# The Effects of Changes in Air Quality on Tourist-Related Industries in a Region: A Theoretical Analysis*

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There is a presumption, generally accepted, that deterioration in air quality has among its effects an impact on the kind of consumption activities enjoyed by consumers. If this is true and the activities affected negatively are supplied by an industry that contributes significantly to a regional GNP, then regional economic planners would be well advised to implement policies to protect the industry from the external diseconomies being generated by other industries. Like most policy arguments having high intuitive appeal, this logic has its flaws.

Presumably it is the region's welfare that is of interest. Then the benefits of relieving the burden of external diseconomies from one industry must be viewed vis-a-vis the costs to the originating sectors. Hence, one's policy analysis cannot afford to be "partial" in perspective.

Perhaps a more basic flaw in the above argument, however, is that it is based on casual empiricism--largely on a presumption. What theoretical justification is there to think reduced air quality does affect consumption patterns? And even if it does, how large is the effect? How would one test for whatever hypotheses might apply here? This paper is addressed to these questions.

The objectives of this paper are three-fold. First, I will attempt to establish some of the theoretical effects of variation in air quality on the allocation of non-work time and income by individuals and families. Put another way, this objective can be viewed as an attempt to discern whether some of the social costs associated with consumer activities are theoretically meaningful. Second, I will try to relate these theoretical effects to a regional economy such as the economy of the Willamette Valley in Oregon. This objective will necessitate that the theoretical model will be rather specific. That is, both the model with which we will work and the implications that are drawn are not expected to hold in all cases at all times but will necessarily draw upon the unique characteristics of the region in question as well as other known institutional and social restrictions. Third, I will attempt to outline possible testing procedures and the data necessary for testing any emergent hypotheses. Any empirical testing of hypotheses, while not to be performed here, would constitute an attempt at testing for the existence if not the size of social costs associated with a class of consumption activities--i.e., these tests would be examining hypotheses of the type 'total cost $X_k >$ market cost $X_k$,' where $X_k$ is a manufactured commodity. As a point of departure, we will begin with a relatively recent contribution to the neoclassical theory of consumer behavior. This model will extend from Gary Becker's work [Economic Journal, September 1965]. I have modified the Becker model for analytical convenience.*

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*For my treatment of the Becker model see my Income Changes and Labor Force Participation, a monograph forthcoming from Oregon State University Press.

Assume an individual with utility function,

1) $U = F(Z_j)$, $j = 1\ldots n$.

Regarding F, we assume this function to be continuous and quasi-concave. Contrary to the neoclassical theory, the arguments in F are not market commodities per se. They are activities. These activities are both produced and consumed by the individual. From the production side, the individual is seen to combine market commodities, $x_{ij}$, and time, $T'_{hj}$, in combinations that are technically defined, and produce the consumption activities, $Z_j$. That is, for each j there is a production function and we can represent this as,

2) $Z_j = f_j(x_{1j}\ldots x_{gj};\ T_{1j}\ldots T_{rj})$ or, in vector form, $Z_j = f_j(x_j,\ T'_j)$.

If the technologies represented by the $f_j$ are linear, the $x_j$ and $T'_j$ can be represented as,

3) $X_j = b_jZ_j$

$T'_j = t_jZ_j$.

In (3), $b_j$ and $T'_j$ are vectors of technical coefficients.

The individual is assumed to maximize F but this process is subjected to two or more constraints. In the simple general case, the constraints are,

4) $\overset{j}{\Sigma}\ t_jZ_j + \Sigma T_s = T$, time constraint

$\overset{j}{\Sigma}\ c_jZ_j + \Sigma w_sT_s = G$, Income constraint.

In (4), the new notation is $t_j = T'_j \cdot 1$, $T_s$ = time worked in occupations, $c_j$ = dollar cost per unit of market commodities used in $Z_j$ and $w_s$ = the wage rate applicable in occupation s -- we are assuming both average and marginal wage rates are equal. G is 'other' nonwage income and T is total time.

The optimization problem viewed here can now be represented as follows:

5) Maximize

$U = F(Z_j)$

s.t.

$\Sigma\ t_jZ_j + \Sigma T_s = T$

$\Sigma\ c_jZ_j + \Sigma w_sT_s = G$

$Z_j \geq 0,\ T_s \geq 0$.

The consumer's problem represented here is a non-linear programming problem. That is, it has a non-linear objective function, two linear constraints and the equilibrium values of the independent variables, $Z_j$ and $T_s$, are permitted to enter an optimal solution at the zero level. At this juncture, we must make some statement about the time period being considered. In the neoclassical theory of consumer behavior, the relevant time period is the 'income period.' In its general form, the problem expressed in (5) can have any reasonable time span. That is, by setting T equal to the sum of hours in a week or month, the time period is specified. However, even here there would be an implicit assumption about regularity in the work-consumption-production process. Certain habitual or institutionally imposed constraints would be recognized--i.e., people may arbitrarily impose sleep periods on the problem between 11 p.m. and 7 a.m. or employers may require that the time period from 8 a.m. to 5 p.m. Monday through Friday be arbitrarily blocked out for work. In the present analysis, however, we are particularly interested in non-work and vacation type activities. Hence, because of the present orientation, the optimization period being viewed here is one in which $T_s = 0$ and total time is viewed as being allocated to consumption and production of activities. This implies that all income is viewed as 'other' income--an observation that will not affect the analysis.

Let us impose an additional simplifying assumption on the present framework by viewing the consumer's problem as one of finding a conditional or planned equilibrium configuration to his optimization problem. If one's vacation involves consumption of activities that are new or novel in the experience field then, to the extent that they are included in the planned equilibrium configuration, the initial decision made toward these activities is dependent upon a set of parameters whose values are, perhaps, based upon incomplete knowledge. For example, actual technical coefficients relating market goods and time to activity levels may be different than the assumed values. When experience provides accurate values for the coefficients, a person may alter his planned level of activity consumption. By viewing this problem as establishing a conditional equilibrium, we leave more flexibility in allowing for the effects of experience on equilibrium activity levels. In this framework and in terms of a generalized Lagrangean function, the problem evolves to

6) $V(Z, \lambda) = F(Z_j) + \lambda_T(T - \Sigma t_j Z_j) + \lambda_y(G - \Sigma c_j Z_j)$, to be maximum

s.t.

$Z_j, \lambda \geq 0$

$j = 1 \ldots n.$

If an optimal solution for this system exists, $Z^o$ and $\lambda^o$, then we must have the following:

7) $V(Z, \lambda^o) \leq V(Z^o, \lambda^o) \leq V(Z^o, \lambda)$

and

8) $\frac{\partial F}{\partial Z_j^o} = \lambda_T^o t_j + \lambda_y^o c_j, \; j \epsilon J$

$\frac{\partial F}{\partial Z_j^o} \leq \lambda_T^o t_j + \lambda_y^o c_j, \; j \epsilon \hat{J}$

$\lambda_T^o, \lambda_y^o, Z_j \geq 0.$

In (6) and (7) the analysis has required the addition of the multipliers $\lambda_T$ and $\lambda_y$. It can be shown that, in terms of this analysis, $\lambda_T$ is the marginal utility of time and $\lambda_y$ is the marginal utility of income. In (7), we have also added some set notation. We have added the set J which is the subset of indicies j that enter the planned equilibrium configuration at positive levels and $\hat{J}$ which is the subset of j that enter at the zero level. Analysis requires $\lambda_T$, $\lambda_y$ and $Z_j$ to be non-negative. The Kuhn-Tucker necessary conditions for an equilibrium are provided in (8).

If optimal solution vectors, $Z^o$ and $\lambda^o$, exist to the problem expressed in (7), then those solution vectors must be such that conditions expressed in (8) hold. The conditions in (8) are the so-called Kuhn-Tucker conditions. These conditions are very similar to those that hold in the traditional consumer equilibrium. That is, for activities consumed at the positive level the marginal utility of each activity must equal the weighted sum of the marginal utilities of time and income--the weights are the appropriate technical coefficients for time and income respectively. For activities consumed at the zero level, the marginal utility of these activities is, reasonably, less than the appropriate weighted sum of the time and income marginal utilities. The equilibrium configuration of consumption activities as well as the optimal values of the relevant marginal utilities are clearly a function of taste, income, the relevant time span, and the technical coefficients relevant for each activity. Variation in any of these can lead to variation in optimal consumption levels of any of the activities. Before considering the question of sensitivity analysis let us inquire further into the character of this equilibrium configuration.

The optimal solution vector, $Z^o$, describes the planned production-consumption levels of activities for this assumed vacation period. With no further information, there is very little we can say about $Z^o$ except the obvious. That is, it will necessarily contain some sleep and eating activities but the character of these activities is not revealed in this general presentation. Among the set of all vacationers, there will be many subsets. We can conceive a subset with strong preferences toward sleeping and, perhaps, gardening; this subset is of no interest here. A second subset may have preferences for and income only adequate to enjoy activities in some close proximity to their home. We can also conceive a subset having tastes for and income adequate to enjoy travel and outdoor activities. It is this group that we want to examine.

If an optimal solution to (7) exists then the Kuhn-Tucker conditions of (8) hold. Let us denote the marginal utilities of activities expressed in (8) as $\phi_j$ These are constants since they are evaluated at a particular point. In the theory of non-linear programming, the optimal solution need not be regarded as permanently fixed. The theory permits variation of parameters and the optimal solution is regarded as holding within some small epsilon area around the optimal solution. The shortest approach to sensitivity analysis would be to regard the Kuhn-Tucker conditions of (8) as the constraints of a linear programming minimizing problem. In this case the variables are the marginal utilities of time and income and the prices in the objective function are expressed in differential terms. This is shown in (9) below:

$$
\begin{array}{ll}
(9) & t_1\lambda_T + c_1\lambda_y \geq \phi_1 \\
 & \vdots \qquad\qquad\quad \vdots \\
 & t_n\lambda_T + c_n\lambda_y \geq \phi_n \\
 & dT\lambda_T + dG\lambda_y = dU \text{ (min)} \\
 & \lambda_T,\ \lambda_y \geq 0
\end{array}
$$

All linear programming problems that have an optimal solution have associated with them a dual problem which also has an optimal solution. The dual may be more convenient here. This is shown in (10) below:

$$
\begin{array}{ll}
10) & t_1dZ_1 \ldots + t_ndZ_n \leq dT \\
 & c_1dZ_1 \ldots + c_ndZ_n \leq dG \\
 & \phi_1dZ_1 \ldots + \phi_ndZ_n = dU \text{ (max)}
\end{array}
$$

In (10) the variables are differentials in consumption activities and the prices in the objective function are the relevant marginal utilities of the activities. This is a maximizing problem.

Parameters that can effect the equilibrium solution include the technical coefficients, available total time, income, and taste for the various consumption activities--taste is embodied in the marginal utilities, $\phi_j$. If parameter changes occur and precipitate changes in optimal activity levels, the non-linear programming analysis requires a compensating set of changes in the vector $\lambda^o$. As it turns out, it is easier to analyze the impact of parameter changes on activity levels by looking at the impact on the multipliers, $\lambda_T$ and $\lambda_Y$.

The dimensions of these multipliers can be easily obtained from (10). Defining B as a basis matrix from (10), it can easily be shown that,

11) $\lambda = \phi_B B^{-1}$.

In this case, the basis matrix would have coefficients from two columns of the constraints in (10) and associated with activity levels consumed at positive levels. For convenience, assume the basis includes coefficients for activity 1 and activity n. The basis matrix would then be,

$$B = \begin{bmatrix} t_1 t_n \\ c_1 c_n \end{bmatrix}$$

Since all bases from (10) would "look alike," assume B is the optimal basis. In this case we would have,

$$12)\quad \lambda_T = \frac{\phi_1 c_n - \phi_n c_1}{t_1 c_n - c_1 t_n}$$

$$\lambda_Y = \frac{\phi_n t_1 - \phi_1 t_n}{t_1 c_n - c_1 t_n} \ .$$

It is usual in the analysis of consumer behavior to treat air quality as constant and independent of the optimal consumption set. Casual experience, however, seems to deny both the assumptions. To discern the effects of variation in air quality on the optimal consumption set, though, an additional assumption must be made. It seems reasonable to assume that deterioration of air quality, as measured by an increase in either eye irritation or horizontal visibility would have negative or zero effects on optimal levels of consumption activities. Put otherwise, we are postulating that an increase in either eye irritation or a reduction in horizontal visibility, will have negative or zero effects on the marginal utilities of activities. With this in mind let us consider the effects of a general change in the "prices" of (10) and, specifically, the effect of a change in the prices $\phi_B$ in (11). Should something occur to change the marginal utilities associated with the optimal consumption set, the effect would be as follows:

$$13)\quad \Delta\lambda = \Delta\phi_B B^{-1}$$

In this two constraint problem and with the assumed optimal basis matrix, B, the effects of (13) are,

$$14)\quad \Delta\lambda_T = \frac{1}{k}(\Delta\phi_1 c_n - \Delta\phi_n c_1)$$

$$\Delta\lambda_Y = \frac{1}{k}(\Delta\phi_n t_1 - \Delta\phi_1 t_n)$$

Prior to looking for empirical implications in (14), a word on the possible effects of parameter changes. A change occurring in the vector $\phi$, if 'small', may leave the optimal solution vector, $Z^o$, unchanged in terms of its activity composition--only the levels of activity consumption may change. On the other hand, "large" changes in $\phi$ may require a whole new solution to our programming problem. Similar observations would apply in the case of other parameter changes. The important thing is that we have no a priori way of knowing what the effect of any given vector change will be on the optimality of a given solution. We are able to make some statements toward the possible changes in activity levels if the equilibrium configuration remains unchanged. With this in mind, we will begin looking at (14) and consider the theoretical effects.

In (14), the term k is the determinant of the basis matrix, B. It cannot be zero. It can be positive or negative. If k is greater than zero, this implies $t_1c_n .. t_nc_1 > 0$, or, alternatively, $c_n/t_n > c_1/t_1$. In words, this says that dollar expenditures per unit of time in the nth activity are greater than the dollars per unit of time in the first activity - i.e., the nth activity is relatively income intensive while the first good is relatively time intensive. The relative income or time intensity of the goods is important here. If k is less than zero, we are implying $c_1/t_1 > c_n/t_n$ -- this implies the relative time and income intensiveness of these goods is reversed. In any event, a priori, the sign of k is unknown. Suppose $k > 0$. If something should happen to $\phi_n$ to reduce it, ceteris paribus, and the change is sufficiently small, we can observe the effects on the relevant marginal utilities of time and income by way of (14). These are:

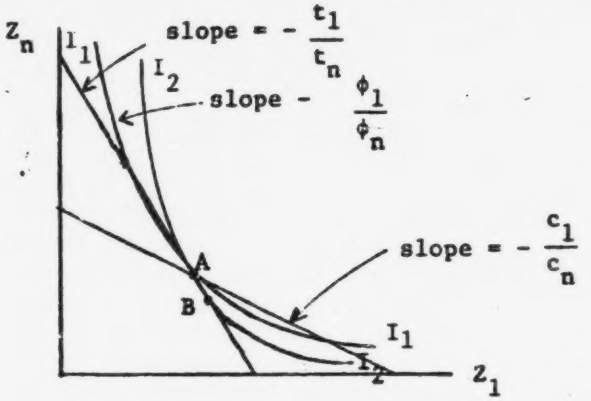
15) $\Delta\lambda_T > 0$

$\Delta\lambda_Y < 0$ .

By assuming k greater than zero we have postulated that the nth activity is "relatively income intensive" and the effect of having the marginal utility of this activity go down has been to raise the marginal utility of time and reduce the marginal utility of income. If the initial change had been in $\phi_1$, the opposite set of sign changes would have occurred in the marginal utilities. Please note, the sign changes in the marginal utilities depend on both the activity whose marginal utility has changed and the sign of k. But it is not the activity so much as its relative time intensity or income intensity that makes the difference. If k had been assumed to be negative, this would have implied the opposite relative time and income intensities for our two activities and in that case a reduction in $\phi_1$ would have raised the marginal utility of time and lowered the marginal utility of income. This is perfectly consistant with the implications already observed.

The changes in the two marginal utilities were precipitated on a change in the marginal utility of one consumption activity. These changes, expressed in (15), have a straightforward interpretation but a word of warning is justified. One must divorce his thinking from the prejudice provided by the sensitivity analysis performed on the traditional theory of consumer behavior. There, parametric changes generally occur in income or market prices and if one observed a reduction in the marginal utility of income this would have implied an increase in the consumption of goods using income. In the present case, the technical income and time resetrictions have been held intact while the utility function has been rotated in favor of one good and away from another. That is, since the utility function has been changed one cannot rely on the assumed quasi-concavitity of that function to interpret changes involving time and income. In the present case, the reduction in $\phi_n$ has had the effect of lowering the opportunity cost of time intensive activities ($Z_1$) with respect to income intensive activities ($Z_n$). That is, one's preference for time or time intensive activities has increased while his preference for income or income intensive activities has decreased. This is tantamount to predicting, as we would expect, that the consumption of $Z_1$ should increase while the consumption of $Z_n$ should decrease.

The implications of this are illustrated diagrammatically in Figure 1, shown below. The two constraints in Figure 1 have been drawn with the relative slopes implied in having $k > 0$. The point A denotes the consumer's equilibrium prior to any change in preferences in this nonlinear programming problem. The reduction in $\phi_n$ has had the effect of twisting the utility surface and the consumer's new equilibrium must be at a point like B. That is, all indifference curves have increased in relative slope and this must move the optimal point to the right. The diagram illustrates what we have just said--that consumption of $Z_1$ should increase while consumption of $Z_n$ should decrease. In this case, $Z_1$ is the time intensive activity while $Z_n$ is the income intensive activity.


$Z_n$
$I_1$
slope = $-\frac{t_1}{t_n}$
$I_2$
slope $-\frac{\phi_1}{\phi_n}$
slope = $-\frac{c_1}{c_n}$
A
B
$I_1$
$I_2$
$Z_1$

The above analysis has outlined some meaningful and potentially testable implications. These are:

1) Tests for the existence of social costs of the type being considered here require the classification or specification of consumption activities and some look at the relative income and time intensities.

2) Given (1), the theoretical implications outlined above can be tested against empirical data on air quality and sales in various product markets--and the hypotheses tested will be relatively 'clean' or unambiguous.

3) If vacation type activities are 'income intensive,' analysis suggests Oregon's economy will suffer in the face of reduced air quality. If these activities are 'time intensive,' the converse is true.

4) The magnitude of these effects depends on the available alternative activities and the character of available activities in adjoining states.

# APPENDIX 2

Selected Tables From:

OREGON STATE HIGHWAY DIVISION
Planning Section
Economics Unit

1971

OUT-OF-STATE

TOURIST REVENUE STUDY

## TABLE II

## SUMMARY OF EXPENDITURES DATA FOR OUT-OF-STATE TRAVELERS
## 1971

### Data Related to Motorists Traveling for Pleasure

| | | |
|---|---|---|
| Of the 8,616 drivers interviewed, the number of vacationers were | | 5,087 |
| Average Passengers Per Car | | 2.7 |
| Average Miles Traveled in Oregon | | 409 |
| Average Days in Oregon | | 3.4 |
| Average Daily Expenditures Per Car | $ | 32.41 |
| Average Trip Expenditures Per Car | $ | 110.19 |
| Total Cars Outbound | | 3,344,900 |
| Total Persons | | 9,092,800 |
| Average Daily Expenditures Per Person | $ | 12.00 |
| Average Trip Expenditures Per Person | $ | 40.81 |

### Data Related to Motorists Traveling on Business

| | | |
|---|---|---|
| Of the 8,616 drivers interviewed, the number of business travelers | | 586 |
| Average Passengers Per Car | | 1.6 |
| Average Miles Traveled in Oregon | | 299 |
| Average Days in Oregon | | 2.9 |
| Average Daily Expenditures Per Car | $ | 29.22 |
| Average Trip Expenditures Per Car | $ | 84.75 |
| Total Cars Outbound | | 402,982 |
| Total Persons | | 644,530 |
| Average Daily Expenditures Per Person | $ | 18.26 |
| Average Trip Expenditures Per Person | $ | 52.97 |

## Data Related to Air, Rail, Bus Travelers

| | | |
|---|---|---|
| Total Persons | | 802,700 |
| Average Trip Expenditures Per Person | $ | 48.09 |

## Data Related to All Visitors and All Modes of Transportation

| | | | |
|---|---|---|---|
| 1. | Out-of-State Passenger Cars<br>Expenditures on Recreation and Pleasure | $ | 365,506,000 |
| 2. | Out-of-State Passenger Cars<br>Expenditures on Business | $ | 34,153,000 |
| 3. | Out-of-State Travelers<br>Air, Rail, Bus | $ | 38,602,000 |
| | Total | $ | 438,261,000 |

---

The statistical data in the first two items in Table II were obtained from a survey conducted during 1971 at all major highway exits from the State. The third item was obtained by analysing information from various sources, including the National Transportation Census for 1967, and preliminary survey data from the Port of Portland's Intermodal Transportation Study.

The statistical data contained in Tables III through XI pertain only to vacationists --- out-of-state passenger cars.

## CLASSIFICATION OF DATA BY STATES & REGIONS

The number of car parties from each of the states of California, Idaho and Washington was large enough to give statistically valid results by classifying the data from these states separately. In addition, Hawaii was classified separately and Canada and Alaska were combined since they do not fit into any conventional regional classification of states.

The following states were grouped by region (See Figure 1), so that meaningful results could be obtained from the sample data:

1. ROCKY MOUNTAIN STATES

   Arizona
   Colorado
   Montana
   New Mexico
   Nevada
   Utah
   Wyoming

2. SOUTH CENTRAL STATES

   Arkansas
   Louisiana
   Oklahoma
   Texas
   Mexico

3. NORTH CENTRAL STATES

   Iowa
   Minnesota
   Missouri
   Nebraska
   North Dakota
   South Dakota
   Kansas

4. EAST CENTRAL STATES

   Illinois
   Indiana
   Michigan
   Ohio
   Wisconsin

5. NORTHEASTERN STATES

   Connecticut
   Maine
   Massachusetts
   New Hampshire
   New Jersey
   New York
   Pennsylvania
   Rhode Island
   Vermont

6. SOUTHEASTERN STATES

   Alabama
   Delaware
   District of Columbia
   Florida
   Georgia
   Kentucky
   Maryland
   Mississippi
   North Carolina
   South Carolina
   Tennessee
   Virginia
   West Virginia

7. CANADA AND ALASKA

8. NOT REPORTED

## DISTRIBUTION OF OUT-OF-STATE DRIVERS INTERVIEWED AND EXPENDITURES BY STATE OR REGION OF REGISTRATION

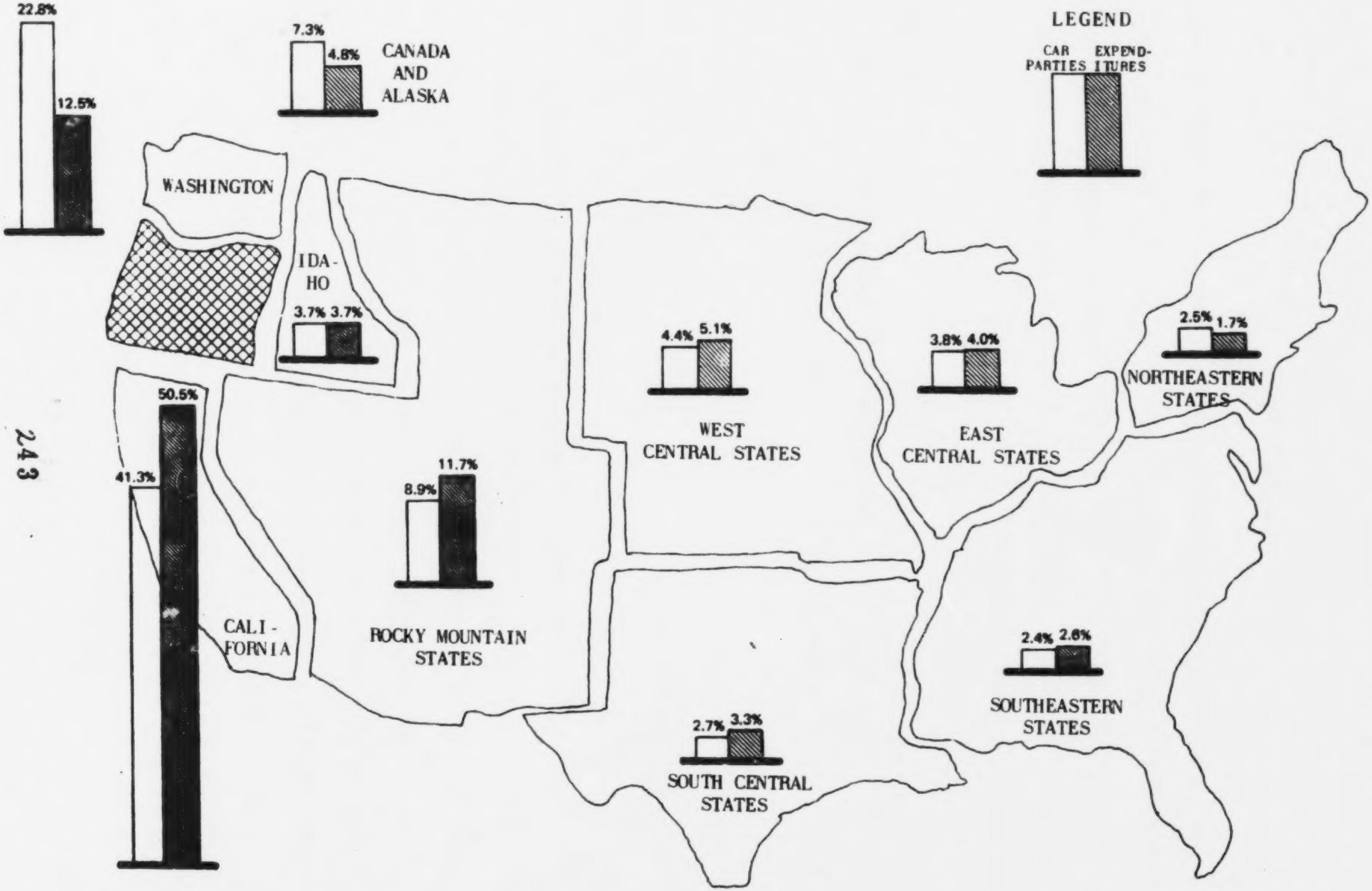

LEGEND
CAR PARTIES
EXPEND-ITURES
22.8%
12.5%
7.3%
4.8%
CANADA AND ALASKA
WASHINGTON
IDA-HO
3.7% 3.7%
41.3%
50.5%
CALI-FORNIA
8.9%
11.7%
ROCKY MOUNTAIN STATES
4.4% 5.1%
WEST CENTRAL STATES
2.7% 3.3%
SOUTH CENTRAL STATES
3.8% 4.0%
EAST CENTRAL STATES
2.5% 1.7%
NORTHEASTERN STATES
2.4% 2.6%
SOUTHEASTERN STATES

Figure 1

# OVERVIEW

Based on information obtained from an interview survey of out-of-state passenger car travelers, it is estimated that out-of-state visitors traveling for pleasure spent $365,506,000 in Oregon in 1971 for food, lodging, recreation, car expenses and other purposes incidental to travel. The significant 1971 data are summarized below with comparative data for 1969 and 1970.

| | 1969 | 1970 | 1971 |
|---|---|---|---|
| Expenditures for Recreation & Pleasure | $ 260,964,000 | $ 272,761,000 | $ 365,506,000 |
| Out-of-State Car Parties | 2,847,000 | 2,815,200 | 3,344,900 |
| Total Persons | 7,710,000 | 7,613,500 | 9,092,800 |
| Average Days in Oregon | 3.4 | 3.5 | 3.4 |
| Average Trip Expenditures in Oregon | $91.66 | $96.89 | $110.19 |

These data show an increase of 18.8% in the number of out-of-state car parties visiting in 1971 compared to 1970, and an increase of 17.5% compared to 1969; with a 34.0% increase in total expenditures over 1970 and 40.0% over 1969.

As has been the case in recent years, tourist expenditures in 1971 increased, and this year the number of tourists visiting Oregon showed a substantial increase. This increase in expenditures is the result of a combination of factors including a large increase in the number of tourists coupled with an increase in per capita spending by these tourists.

The very substantial increase in the number of tourists this year of 19.4% over 1970 is in main due to the abnormally low number of tourists visiting the State in 1970, which registered a loss of 1.3% over 1969. Thus, the average annual increase over the two year period (1969-71) was a more modest 8.9% per year. It appears that the large increase in 1971 put the industry back on its larger term growth curve with respect to number of tourists.

The increase in number of tourists, then accounts for 19.4% of the 34.0% increase in expenditures between 1970 and 1971 with the remaining increase being the result of the increase in average expenditures per person per day.

## ORIGIN OF VISITORS

The data in Tables III, IV and Figure 1, show that the adjacent states of California and Washington provide the bulk of Oregon's tourist trade. From these two states come the greatest number of tourists, as well as the greatest contribution of tourist dollars spent in Oregon in 1971.

In 1971, over 1.38 million car parties from California vacationing in Oregon spent 184.7 million dollars, accounting for 41.4% of the passenger car tourists coming to the State, and 50.5% of the total expenditures made by such tourists. The State of Washington provided a significant 22.8% of the total car parties vacationing in Oregon in 1971, but contributed only 12.5% of the expenditures due to their much shorter length of stay; an average of 2.0 days in Oregon as compared to the 3.4 day average for all visitors.

The Rocky Mountain States accounted for the third largest group of visitors to Oregon. Motoring tourists vacationing from this area stayed an average of 0.5 days more in Oregon than did the average visitor, and spent more than four dollars per day per car party more than the average. Thus, while this area provided only 8.9% of the car parties visiting Oregon, it accounted for 11.7% of the expenditures.

Following Washington, California and the Rocky Mountain States in dollar volume of tourist trade, were the North Central States. This area had 4.4% of the out-of-state car parties, and 5.1% of the total tourist expenditures in Oregon.

After the North Central States, the greatest tourist expenditures came from residents of Canada and Alaska, followed in the order of dollar volume by East Central States, Idaho, South Central States, Southeastern States, and the Northeastern States.

The regions having the highest dollar return per car party while in Oregon were the Rocky Mountain, California and South Central, while the States of Washington and Hawaii experienced the lowest. The primary factor contributing to this difference in return per car party was that tourists from these regions stayed longer or had larger car parties on the average than did tourists from Washington and Hawaii. To illustrate, one car party from the Rocky Mountain States in terms of expenditures was worth about 2.4 car parties from the State of Washington.

## TABLE III

## DISTRIBUTION OF CAR PARTIES AND EXPENDITURES BY ORIGIN

| State or Region | Number of Car Parties | % of Car Parties | Number of Persons | % of Persons | $ Expenditures | % of Expen tures |
|---|---|---|---|---|---|---|
| | (000) | | (000) | | (000) | |
| California | 1,383.1 | 41.3 | 3,898.1 | 42.9 | 184,653 | 50.5 |
| Hawaii | 2.0 | 0.1 | 10.0 | 0.1 | 37 | - - |
| Idaho | 123.4 | 3.7 | 300.1 | 3.3 | 13,523 | 3.7 |
| Washington | 763.0 | 22.8 | 1,970.4 | 21.7 | 45,652 | 12.5 |
| Rocky Mountain States | 297.0 | 8.9 | 792.9 | 8.7 | 42,728 | 11.7 |
| South Central States | 91.0 | 2.7 | 238.2 | 2.6 | 11,952 | 3.3 |
| North Central States | 148.2 | 4.4 | 480.1 | 5.3 | 18,568 | 5.1 |
| East Central States | 126.8 | 3.8 | 370.1 | 4.1 | 14,511 | 4.0 |
| Northeastern States | 82.3 | 2.5 | 217.3 | 2.4 | 6,396 | 1.7 |
| Southeastern States | 80.6 | 2.4 | 182.8 | 2.0 | 9,576 | 2.6 |
| Canada and Alaska | 243.2 | 7.3 | 622.8 | 6.8 | 17,581 | 4.8 |
| Not Reported | 4.3 | 0.1 | 10.0 | 0.1 | 329 | 0.1 |
| TOTAL | 3,344.9 | 100.0 | 9,092.8 | 100.0 | 365,506 | 100.0 |

## TABLE IV

### AVERAGE DAYS IN OREGON, AVERAGE PEOPLE PER CAR, AVERAGE DAILY EXPENDITURES PER CAR, AVERAGE MILES TRAVELED IN OREGON, AND AVERAGE EXPENDITURES PER CAR PARTY

| State or Region | Average Days in Oregon | Average People Per Car | Avg. Daily Expendi- Per Car ($) | Avg. Miles Traveled in Oregon | Average Expenditures Per Car Party ($) |
|---|---|---|---|---|---|
| California | 4.0 | 2.8 | 33.53 | 441 | 134.12 |
| Hawaii | 1.1 | 5.0 | 16.20 | 341 | 17.82 |
| Idaho | 3.8 | 2.4 | 28.48 | 431 | 108.22 |
| Washington | 2.0 | 2.6 | 29.55 | 313 | 59.10 |
| Rocky Mountain States | 3.9 | 2.7 | 36.68 | 449 | 143.05 |
| South Central States | 4.9 | 2.6 | 26.83 | 431 | 131.47 |
| North Central States | 4.1 | 3.2 | 30.89 | 472 | 126.65 |
| East Central States | 3.3 | 2.9 | 34.96 | 406 | 115.37 |
| Northeastern States | 2.7 | 2.6 | 28.94 | 450 | 78.14 |
| Southeastern States | 3.7 | 2.3 | 31.92 | 455 | 118.10 |
| Canada and Alaska | 2.4 | 2.6 | 29.92 | 394 | 71.81 |
| Not Reported | 3.1 | 2.3 | 24.31 | 377 | 75.36 |
| TOTAL | 3.4 | 2.7 | 32.41 | 409 | 110.19 |

# APPENDIX 3

## Interview Instrument

Budget Bureau Number OMB 158-S71017
Approval Expires April 30, 1972

August 9, 1971 OREGON STATE UNIVERSITY Final

Hello, I'm working on a survey for Oregon State University and I would like to ask you a few interesting questions, if you don't mind.

---

| | |
|---|---|
| 1- ______________________ City<br>______________________ State | First, which city is your permanent residence located in or near? |

(NOTE TO INTERVIEWER: If respondent resides in Oregon, terminate interview; otherwise continue)

| | |
|---|---|
| 2- 1 Recreation (Ask Q3)<br>2 Other only (TERMINATE)<br>(Specify ______________)<br>3 Both recreation & other (Ask Q3) | Are you traveling in Oregon for recreation or for other purposes? |
| 3- 1 Auto<br>2 Bus (commercial)<br>3 Airplane<br>4 Other (Specify __________) | What type or types of transportation are you using on your vacation or recreation trip in Oregon? |

4- Thinking back to just before you left on your vacation or recreation trip, which place or places were you planning to visit in Oregon?

________________ ________________ ________________

5- Again, thinking back to just before you left on your vacation or recreation trip, how many days were you planning to spend in Oregon?

________________

6- Again, thinking back to just before you left on your vacation or recreation trip, which highway or highways were you planning to use in Oregon to get to your destination(s)?

________________________________________

________________________________________

7- And, which highway or highways were you planning to use to leave Oregon?

________________________________________

8-

| L | QB | LI | N | DK | |
|---|---|---|---|---|---|
| 4 | 3 | 2 | 1 | 0 | Camping |
| 4 | 3 | 2 | 1 | 0 | Boating, Water skiing |
| 4 | 3 | 2 | 1 | 0 | Golfing |
| 4 | 3 | 2 | 1 | 0 | Ocean beach activities |
| 4 | 3 | 2 | 1 | 0 | Hiking, walking |
| 4 | 3 | 2 | 1 | 0 | Swimming |
| 4 | 3 | 2 | 1 | 0 | Pleasure driving sightseeing |
| 4 | 3 | 2 | 1 | 0 | Salmon fishing |
| 4 | 3 | 2 | 1 | 0 | Trout fishing |
| 4 | 3 | 2 | 1 | 0 | Other (Specify ________) |

Now, here are some specific out-of-door activities. Thinking back to just before you left on this trip, how much time, if any, were you planning to spend participating in each of these activities in Oregon? As I read each activity would you tell me how much time you planned to spend on each one--a lot, quite a bit, a little or none at all?

- $______________

Including everyone in your party, about how much, in dollars, were you planning to spend in Oregon for your vacation in the state this summer? Just your best estimate?

---

0- Which place or places have you already visited in Oregon on this particular vacation or recreation trip?

____________ ____________ ____________

---

1- Considering your vacation plans now, which place or places are you planning to visit in Oregon?

____________ ____________ ____________

---

2- And, considering your vacation plans now, which highway or highways are you planning to use to get to your destination(s) in Oregon?

______________________________

______________________________

---

3- Which highway or highways are you planning to use now when you leave Oregon?

______________________________

---

4- How many days will you spend in Oregon?

____________

---

5- Here are some out-of-door activities. How much time, if any, are you planning to spend now participating in them in Oregon. As I read each activity will you tell me the time you plan to spend now on each one -- a lot, quite a bit, a little or none at all?

| L | QB | LI | N | DK | |
|---|---|---|---|---|---|
| 4 | 3 | 2 | 1 | 0 | Camping |
| 4 | 3 | 2 | 1 | 0 | Boating, water skiing |
| 4 | 3 | 2 | 1 | 0 | Golfing |
| 4 | 3 | 2 | 1 | 0 | Ocean beach activities |
| 4 | 3 | 2 | 1 | 0 | Hiking, walking |
| 4 | 3 | 2 | 1 | 0 | Swimming |
| 4 | 3 | 2 | 1 | 0 | Pleasure driving sightseeing |
| 4 | 3 | 2 | 1 | 0 | Salmon Fishing |
| 4 | 3 | 2 | 1 | 0 | Trout Fishing |
| 4 | 3 | 2 | 1 | 0 | Other (Specify________) |

---

5- The way things look now, will you probably spend more or less money on your vacation in Oregon than you originally planned to?

1 More (Ask Q16a)
2 Less (Ask Q16a)
3 Same (Skip to Q17)
4 DK (Skip to Q17)

a- What are the main reasons you will probably spend (more) (less) than you originally planned to? (PROBE)

---

7- Have your vacation plans for Oregon changed since you arrived in the state, or not?

1 Changed (Ask Q18)
2 Not changed (Skip to Q25)
3 DK, NA (Skip to Q25)

18- I have here a list of reasons some people have given for changing vacation plans in Oregon. As I read each one, would you tell me if it had any effect or not on your plans?

| Yes | No | DK, NA | |
|---|---|---|---|
| 2 | 1 | 0 | Rain |
| 2 | 1 | 0 | Heat |
| 2 | 1 | 0 | Crowded facilities (What?________) |
| 2 | 1 | 0 | Air pollution |
| 2 | 1 | 0 | Lack of money |
| 2 | 1 | 0 | Automobile breakdown or accident |
| 2 | 1 | 0 | Sickness in family |
| 2 | 1 | 0 | Other (What?____________) |

(INTERVIEWER: Always ask #19 if code 2 on Air pollution is circled.)
If Air pollution code 2 is not circled, skip to #23)

---

19- What kind or kinds of air pollution in Oregon affected your vacation plans in the state this summer? (PROBE for type and location of air pollution)

---

20- How or in what way or ways did air pollution in Oregon affect your vacation plans in this state? (PROBE!)

---

| | |
|---|---|
| 21- 1 Increased (Ask Q22)<br>2 Decreased (Ask Q22)<br>3 No difference (Skip to Q23)<br>4 DK, NA (Skip to Q23) | Would you say that air pollution in Oregon increase<br>or decreased the amount of money you planned to spend for your vacation in the state this summer? |

| | |
|---|---|
| 8 $501 or more<br>7 $301 - $500<br>6 $201 - $300<br>5 $101 - $200<br>22- 4 $ 51 - $100<br>3 $ 26 - $ 50<br>2 $ 11 - $ 25<br>1 $ 1 - $ 10 | (HAND RESPONDENT CARD A)<br>Would you please look at this card and tell me which one of these groups best fits the (increase) (decrease) in dollars, your party is spending in Oregon for your vacation because of air pollution? |

| | |
|---|---|
| 23- 1 Increase (Ask Q24)<br>2 Decrease (Ask Q24)<br>3 No difference (Skip to Q25)<br>4 DK, NA (Skip to Q25) | (Not counting air pollution) Would you say that the reasons you gave for changing vacation plans in Oregon increased or decreased the amount of money you planned to spend for your vacation in the state this summer? |

| | |
|---|---|
| 8 $501 or more<br>7 $301 - $500<br>6 $201 - $300<br>5 $101 - $200<br>24- 4 $ 51 - $100<br>3 $ 26 - $ 50<br>2 $ 11 - $ 25<br>1 $ 1 - $ 10 | (HAND RESPONDENT CARD A)<br>(Not counting air pollution) Would you please look at this card and tell me which one of these groups best fits the (increase)(decrease) in the amount of money you planned to spend for your vacation in the state this summer? |

| | | |
|---|---|---|
| 5- | 1 Very<br>2 Quite<br>3 Not too<br>4 Not at all<br>5 DK | From what you have seen in Oregon, how serious an air pollution problem, if any, do you feel we have-very serious, quite serious, not too serious or not serious at all? |
| 6- | 1 Very (Ask 26a)<br>2 Quite (Ask Q26a)<br>3 Not too (Ask Q26a)<br>4 Not at all (Ask Q26a)<br>5 DK (Skip to Q27) | How serious an air pollution problem, if any, do you feel you have in the area where you live--very serious, quite serious, not too serious or not serious at all? |
| 6a | How or in what way or ways is air pollution a _________ problem in the area where you live? (PROBE) | |
| 7- | 1 More in Oregon (Ask Q27a)<br>2 Less in Oregon (Ask Q27a)<br>3 Same (Skip to Q28)<br>4 DK (Skip to Q28) | Thinking about clean air again, would you say there is more or less air pollution in Oregon than where you live? |
| 7a | How, or in what ways, do you think Oregon has (more) (less) of an air pollution problem than the place where you live? | |
| 8- | ASK OF EVERYONE<br>_____________<br>no. of persons | Including yourself, how many persons are traveling in your party on this particular vacation or recreation trip in Oregon? |
| 9- | 4 College - complete<br>3 College - partial<br>2 High School<br>1 Grade or no schooling | Would you mind telling me the last grade you completed in school? |
| 0- | _____________(Type of industry)<br>_____________(Specific job) | What type of work does the chief breadwinner in the family do? |
| 1- | 1 20-29<br>2 30-39<br>3 40-49<br>4 50-59<br>5 60 & above | May I ask your approximate age? |
| 2- | BY OBSERVATION<br>1 Male<br>2 Female | |

| | | |
|---|---|---|
| 33- | 1 Less than 30 minutes<br>2 30 minutes - 1 hour<br>3 1 hour - 1 1/2 hours<br>4 More than 1 1/2 hours | Length of interview |

34- License number ________________

| | | |
|---|---|---|
| 35- | 3 Positive<br>2 Neutral<br>1 Negative | Rating on cooperation. |

X I hereby certify this interview was actually taken at the following address and represents a true and accurate account of the interview.

____________________ (Address ____________________ (City) ____________________ (Interviewer's Signature)

____________________ Phone Number (For verification only) Name____________________

FOR OFFICE USE ONLY: Interview verified by ____________________ Date__________

# APPENDIX 4

## Questionnaire Derived Data Arranged by Closed Ended and Open Ended Type Questions

## A. Closed Ended Question Responses

### Q1) Location and Size of Permanent Residence

| State: | Total |
|---|---|
| California | 54% |
| Washington | 20 |
| Other western states | 9 |
| Canada | 6 |
| Midwestern states | 5 |
| Southern states | 4 |
| Eastern states | 2 |
| New England states | # |
| Total | 100% |
| (Sample) | (401) |

| Size of Home City: | |
|---|---|
| Less than 2,500 | 9% |
| 2,500 - 24,999 | 23 |
| 25,000 - 49,999 | 12 |
| 50,000 - 99,999 | 15 |
| 100,000 - 299,999 | 13 |
| 300,000 - 499,999 | 6 |
| 500,000 or more | 22 |
| Total | 100% |
| (Sample) | (401) |

---

Note: # = Less than 0.5%

### Q2) Purpose of Trip

| Purpose: | Number | Percent |
|---|---|---|
| Recreation | 341 | 85.0 |
| Other only | 0 | 0 |
| Both recreation and other | 60 | 15.0 |
| Total | 401 | 100.0 |

### Q3) Type of Transportation

| Mode: | Number | Percent |
|---|---|---|
| Auto | 362 | 90.3 |
| Bus (commercial) | 9 | 2.2 |
| Airplane | 5 | 1.2 |
| Other | 8 | 2.0 |
| Auto & Airplane | 16 | 4.0 |
| Auto & Bus | 1 | 0.2 |
| Total | 401 | 100.0 |

### Q5,14) Length of Vacation in Oregon

|  | (Q5) | (Q14) |
|---|---|---|
|  | Number of Days Planning to Spend: |  |
| Time: | Originally | Currently |
| 3 days or less | 39% | 39% |
| 4 - 6 days | 21 | 24 |
| 1 week - 1 week, 6 days | 22 | 23 |
| 2 weeks - 2 weeks, 6 days | 8 | 6 |
| 3 weeks - 3 weeks, 6 days | 2 | 2 |
| 4 weeks or longer | 4 | 4 |
| Undecided | 4 | 2 |
| Totals | 100% | 100% |
| Samples | (401) | (401) |

Q8) Planned Use of Time in Specific Outdoor Activities

| Activity | A Lot | | Quite A Bit | | A Little | | None | | Don't Know | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | # | % | # | % | # | % | # | % | # | % | |
| Camping | 44 | 11.0 | 17 | 4.2 | 26 | 6.5 | 303 | 75.6 | 11 | 2.7 | 401 |
| Boating, Water skiing | 17 | 4.2 | 6 | 1.5 | 29 | 7.2 | 341 | 85.0 | 8 | 2.0 | 401 |
| Golfing | 10 | 2.5 | 6 | 1.5 | 26 | 6.5 | 348 | 86.8 | 11 | 2.7 | 401 |
| Ocean beach activities | 54 | 13.4 | 45 | 11.2 | 97 | 34.1 | 202 | 50.3 | 3 | 0.7 | 401 |
| Hiking, walking | 36 | 9.0 | 48 | 12.0 | 200 | 49.9 | 175 | 43.6 | 2 | 0.5 | 401 |
| Swimming | 40 | 10.0 | 45 | 11.2 | 99 | 24.7 | 210 | 52.4 | 7 | 1.7 | 401 |
| Pleasure driving, sightseeing | 206 | 51.3 | 91 | 22.6 | 62 | 15.4 | 41 | 10.2 | 1 | 0.2 | 401 |
| Salmon fishing | 21 | 5.2 | 8 | 2.0 | 21 | 5.2 | 341 | 85.0 | 10 | 2.5 | 401 |
| Trout fishing | 8 | 2.0 | 16 | 4.0 | 31 | 7.7 | 336 | 83.8 | 10 | 2.5 | 401 |
| Other | 37 | 9.2 | 18 | 4.5 | 29 | 7.2 | 312 | 77.8 | 5 | 1.2 | 401 |

Q9) Amount of Money Planning to Spend in Oregon

| Dollars: | Total |
|---|---|
| Under $100 | 26% |
| $100 - $199 | 20 |
| $200 - $299 | 10 |
| $300 - $399 | 4 |
| $400 - $499 | 3 |
| $500 - $599 | 2 |
| $600 - $699 | # |
| $700 - $799 | 2 |
| $800 - $999 | 2 |
| $1,000 - $1,499 | 25 |
| $1,500 or more | 1 |
| Undecided | 5 |
| Total | 100% |
| (Sample) | (401) |
| Average (Median) Amount Planning to Spend | $206.40 |

Note: # = Less than 0.5%

Q15) Present (in trip) Planned Use of Time in Specific Outdoor Activities (read down)

|  | A Lot |  | Quite A Bit |  | A Little |  | None |  | Don't Know |  | Total Responses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity | # | % | # | % | # | % | # | % | # | % |  |
| Camping | 36 | 9.0 | 15 | 3.7 | 28 | 7.0 | 311 | 77.6 | 11 | 2.7 | 401 |
| Boating, Water skiing | 12 | 3.0 | 9 | 2.2 | 23 | 5.7 | 344 | 85.8 | 13 | 3.2 | 401 |
| Golfing | 11 | 2.7 | 6 | 1.5 | 22 | 5.5 | 347 | 86.5 | 15 | 3.7 | 401 |
| Ocean beach activities | 44 | 11.0 | 36 | 9.0 | 96 | 24.0 | 221 | 55.1 | 4 | 1.0 | 401 |
| Hiking, walking | 34 | 8.5 | 39 | 9.7 | 136 | 33.8 | 188 | 46.8 | 5 | 1.2 | 401 |
| Swimming | 34 | 8.5 | 38 | 9.5 | 94 | 23.4 | 227 | 56.6 | 8 | 2.0 | 401 |
| Pleasure driving sightseeing | 201 | 50.1 | 85 | 21.2 | 55 | 13.7 | 59 | 14.7 | 6 | 1.5 | 401 |
| Salmon Fishing | 17 | 4.2 | 8 | 2.0 | 21 | 5.2 | 344 | 85.6 | 11 | 3.0 | 401 |
| Trout Fishing | 4 | 1.0 | 13 | 3.2 | 30 | 7.5 | 343 | 85.5 | 11 | 2.7 | 401 |
| Other | 33 | 8.2 | 15 | 3.7 | 22 | 5.5 | 325 | 81.0 | 6 | 1.5 | 401 |

Q16) Have Spending Plans for Oregon Been Changed? (read down)

| Response | Number | Percent |
|---|---|---|
| Yes - Will spend more | 97 | 24.2 |
| Yes - Will spend less | 41 | 10.2 |
| No change | 237 | 59.1 |
| Don't know | 26 | 6.5 |
| Total | 401 |  |

Q17) Have Vacation Plans for Oregon Changed Since Arriving in the State? (read down)

| Response | Number | Percent |
|---|---|---|
| Changed | 59 | 14.7 |
| No change | 340 | 84.8 |
| Don't know or no answer | 2 | .5 |
| Total | 401 |  |

Q18) Reasons for Changing Vacation Plans. (read down)

| Reasons | Yes # | Yes % | No # | No % | Don't Know No Answer # | Don't Know No Answer % | Total |
|---|---|---|---|---|---|---|---|
| Rain | 15 | 3.2 | 44 | 9.3 | 0 | 0 | 59 |
| Heat | 0 | 0.0 | 59 | 12.5 | 0 | 0 | 59 |
| Crowded facilities | 11 | 2.3 | 48 | 10.2 | 0 | 0 | 59 |
| Air pollution | 6 | 1.3 | 53 | 11.2 | 0 | 0 | 59 |
| Lack of money | 2 | .4 | 57 | 12.1 | 0 | 0 | 59 |
| Auto breakdown or accident | 6 | 1.3 | 52 | 11.0 | 0 | 0 | 59 |
| Sickness in family | 5 | 1.1 | 54 | 11.5 | 0 | 0 | 59 |
| Other | 30 | 6.4 | 29 | 6.2 | 0 | 0 | 59 |

Q21) Impact of Air Pollution on Spending Plans. (read down)

| Response | Number | Percent |
|---|---|---|
| Spending increased | 0 | 0 |
| Spending decreased | 5 | 83.3 |
| No difference | 1 | 16.7 |
| Don't know or no answer | 0 | 0 |
| Total | 6 | |

Q22) Magnitude of Impact of Air Pollution on Spending Plans in Oregon. (read down)

| Dollar Impact | Number | Percent |
|---|---|---|
| $501 or more | 0 | 0 |
| $301 - $500 | 0 | 0 |
| $201 - $300 | 0 | 0 |
| $101 - $200 | 2 | 40.0 |
| $ 51 - $100 | 1 | 20.0 |
| $ 25 - $ 50 | 2 | 40.0 |
| $ 11 - $ 25 | 0 | 0 |
| $ 1 - $ 10 | 0 | 0 |
| Total | 5 | |

Q23) Exclusive of Air Pollution Have the Reasons for Changing Vacation Plans in Oregon Increased or Decreased Spending Plans in the State. (read down)

| Direction of Change | Number | Percent |
|---|---|---|
| Increased | 22 | 36.8 |
| Decreased | 13 | 22.8 |
| No difference | 21 | 33.3 |
| Don't know, no answer | 3 | 7.0 |
| Total | 59 | |

Q24) Exclusive of Air Pollution, the Dollar Magnitude of Vacation Plan Change Impact. (read down)

| Dollar Impact | Number | Increase | Decrease | Percent |
|---|---|---|---|---|
| Don't know | 2 | 2 | 0 | 5.7 |
| $501 or more | 2 | 2 | 0 | 5.7 |
| $301 - $500 | 1 | 1 | 0 | 2.9 |
| $201 - $300 | 5 | 5 | 0 | 14.3 |
| $101 - $200 | 2 | 1 | 1 | 5.7 |
| $ 51 - $100 | 12 | 5 | 7 | 34.3 |
| $ 26 - $ 50 | 7 | 3 | 4 | 20.0 |
| $ 11 - $ 25 | 3 | 3 | 0 | 8.6 |
| $ 1 - $ 10 | 1 | 0 | 1 | 2.9 |
| Total | 35 | 22 | 13 | |

Q25) How Serious an Air Pollution Problem does Oregon Have. (read down)

| Seriousness | Number | Percent |
|---|---|---|
| Very | 37 | 9.2 |
| Quite | 39 | 9.7 |
| Not too | 181 | 45.1 |
| No problem | 136 | 33.9 |
| Don't know | 8 | 2.0 |
| Total | 401 | |

Q26) Seriousness of Air Pollution Problem in Home Area. (read down)

| Seriousness | Number | Percent |
|---|---|---|
| Very | 149 | 37.1 |
| Quite | 74 | 18.4 |
| Not too | 112 | 27.9 |
| No problem | 64 | 15.9 |
| Don't know | 2 | .7 |
| Total | 401 | |

Q27) Regarding Air Pollution in Oregon vis-a-vis Home Area. (read down)

| Relative Pollution | Number | Percent |
|---|---|---|
| More in Oregon | 71 | 17.7 |
| Less in Oregon | 245 | 61.1 |
| Same as home area | 63 | 15.7 |
| Don't know | 6 | 1.5 |
| Qualified "less in Oregon" | 16 | 4.0 |
| Total | 401 | |

Q28) Number of Persons in Party (read down)

| Number in Party | Number | Percent |
|---|---|---|
| 1 | 21 | 5.0 |
| 2 | 159 | 40.0 |
| 3 | 62 | 15.0 |
| 4 | 81 | 20.0 |
| 5 | 43 | 11.0 |
| 6 | 23 | 6.0 |
| 7 | 6 | 1.0 |
| 8 | 4 | 1.0 |
| 9 | 2 | .5 |
| Total | 401 | |

Q29) Educational Characteristics of Respondents. (read down)

| Education | Number | Percent |
|---|---|---|
| Completed college | 147 | 3.5 |
| Partial college | 99 | 35.2 |
| High school | 141 | 24.0 |
| Grade school or no school | 14 | 36.7 |
| Total | 401 | |

Q31) Age Characteristics of respondents. (read down)

| Age | Number | Percent |
|---|---|---|
| 20 - 29 | 56 | 14.0 |
| 30 - 39 | 85 | 21.2 |
| 40 - 49 | 100 | 24.9 |
| 50 - 59 | 90 | 22.4 |
| 60 & above | 70 | 17.5 |
| Total | 401 | |

Q32) Sex Characteristics of Respondents. (read down)

| Sex | Number | Percent |
|---|---|---|
| Male | 243 | 60.6 |
| Female | 158 | 39.4 |
| Total | 401 | |

Q33) Length of Interview. (read down)

| Time | Number | Percent |
|---|---|---|
| Less than 30 minutes | 304 | 75.8 |
| 30 minutes - 1 hour | 82 | 20.4 |
| 1 hour - 1½ hours | 15 | 3.7 |
| More than 1½ hours | 0 | 0.0 |
|  | Total 401 |  |

Q35) Rating on Cooperation. (read down)

| Attitude | Number | Percent |
|---|---|---|
| Positive | 361 | 90.0 |
| Neutral | 33 | 8.2 |
| Negative | 7 | 1.7 |
|  | Total 401 |  |

B. Open Ended and Multiple Response Questions

Q4,10,11) Areas in Oregon Included in Vacation Plans. (Read down)

| Area(s): | (Q4) Original Places Planning to Visit | (Q10) Places Already Visited | (Q11) Current Places Planning to Visit |
|---|---|---|---|
| Valley cities . . . . . . . . . . . | 41% | 42% | 22% |
| Valley recreational areas . . . . . . . . . . . . . . . | 8 | 9 | 5 |
| Costal recreational areas . . . . . . . . . . . . . . . | 32 | 19 | 15 |
| Coastal cities . . . . . . . . . . . | 25 | 27 | 14 |
| Portland . . . . . . . . . . . . . . | 23 | 22 | 15 |
| Crater Lake . . . . . . . . . . . . . | 13 | 11 | 14 |
| Central cities . . . . . . . . . . . | 10 | 12 | 8 |
| Central recreational areas . . . . . . . . . . . . . . . | 4 | 7 | 3 |
| Columbia River . . . . . . . . . . . | 5 | 8 | 3 |
| Interior cities . . . . . . . . . . . | 3 | 2 | 2 |
| Interior recreational areas . . . . . . . . . . . . . . . | # | 1 | 1 |
| No plans . . . . . . . . . . . . . . | 9 | 10 | 35 |
| Totals 1/ . . . . | 173% | 170% | 137% |
| (Samples) . . . . | (401) | (401) | (401) |

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1/ Results total more than 100%, due to vacation planning which included more than one area.

Note: # = Less than 0.5%.

Q6,7,12,13) Use of Oregon Highways. (Read down)

| Highways(s): | (Q6) Originally Planning to Use: to Destination | (Q7) Originally Planning to Use: to Leave Oregon | (Q12) Currently Planning to Use: to Destination | (Q13) Currently Planning to Use: to Leave Oregon |
|---|---|---|---|---|
| I-5 | 66% | 51% | 49% | 50% |
| 101 | 43 | 27 | 29 | 25 |
| 97 | 19 | 14 | 18 | 13 |
| 30 or 80N | 13 | 7 | 7 | 7 |
| 20 | 7 | 3 | 5 | 3 |
| 26 | 6 | # | 2 | # |
| 99 | 5 | 5 | 3 | 4 |
| 22 | 3 | 2 | 2 | 2 |
| 58 | 2 | 2 | 2 | 2 |
| 395 | 2 | 1 | 1 | 1 |
| 126 | 2 | # | 6 | 1 |
| All others; airlines | 19 | 10 | 14 | 13 |
| No plans | 2 | 4 | 9 | 3 |
| Totals 1/ | 189% | 126% | 147% | 124% |
| (Samples) | (401) | (401) | (401) | (401) |

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1/ Results total more than 100%, due to use of more than one highway.

Note: # = Less than 0.5%.

Q16a) Reasons for Spending Less Money in Oregon than Originally Planned. (Read down)

| Reason(s): | Total Spending Less |
|---|---|
| Cut vacation short; injuries forced us to leave; illness . . . . . . . . . . . . . . . . | 39% |
| Lodging is less expensive; stayed with relatives; camped more; gas is less . . . . . . . . . . . . . . . . . . . . . | 24 |
| Air pollution, smog . . . . . . . . . . . . . . . . | 7 |
| Rain, didn't get to fish . . . . . . . . . . . . . . | 5 |
| Season closed for clams . . . . . . . . . . . . . . | 2 |
| No vacancies . . . . . . . . . . . . . . . . . . . . | 2 |
| No sales tax . . . . . . . . . . . . . . . . . . . . | 2 |
| Well-marked roads . . . . . . . . . . . . . . . . . | 2 |
| No reason; just saved to have money left over . . . . . . . . . . . . . . . . . . | 7 |
| Miscellaneous . . . . . . . . . . . . . . . . . . . | 5 |
| Undecided . . . . . . . . . . . . . . . . . . . . . | 7 |
| Total 1/ . . . . . . . . . . . | 102% |
| (Sample) . . . . . . . . . . . | (41) |

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1/ Results total more than 100%, due to multiple response.

Q16a) Reasons for Spending More Money in Oregon than Originally Planned. (Read down)

| Reason(s): | Total Spending More |
|---|---|
| Unplanned activities; more to do than we thought | 51% |
| Lodging is expensive; used camper less than planned; high(er) prices | 20 |
| Picked up souvenirs and gifts | 18 |
| Car repairs; needed tires | 8 |
| Purchased fishing gear | 3 |
| Illness; doctor bills and medicine | 1 |
| Undecided | 2 |
| Total 1/ | 103% |
| (Sample) | (97) |

Q26a) Reasons for Feeling Air Pollution is NOT a Serious Problem in Home Area. (Read down)

| Reason(s): | Total Feeling NOT Serious |
|---|---|
| Less industry | 41% |
| Open country; beach winds; open spaces; high altitude | 24 |
| Less pollution from automobiles | 17 |
| Fewer people | 8 |
| Not as many lumber mills; lumbering has less pollutants than other industry | 5 |

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1/ Results total more than 100%, due to multiple response.

Q26a) Reasons for Feeling Air Pollution is NOT a Serious Problem in Home Area. (Read down) (continued)

| Reason(s): | Total Feeling NOT Serious |
|---|---|
| Ban on field burning; less burning . . . . . . . . | 2 |
| Fewer pulp and paper operations . . . . . . . . . | 2 |
| Absence of respiratory ailments . . . . . . . . . | 2 |
| Fewer farms . . . . . . . . . . . . . . . . . . . | 1 |
| Airports and air traffic not as bad . . . . . . . . . . . . . . . . . . . . . | 1 |
| Miscellaneous; proper preventive legislation; well-controlled . . . . . . . . . . . . | 7 |
| Undecided . . . . . . . . . . . . . . . . . . . . | 20 |
| Total 1/ . . . . . . . . . . . | 130% |
| (Sample) . . . . . . . . . . . | (176) |

Q26a) Reasons for Feeling Air Pollution is a Serious Problem in Home Area. (Read down)

| Reason(s): | Total Feeling Serious |
|---|---|
| Industrial pollution; chemicals; oil refinery; iron smelters; aluminium plants; fertilizer factories . . . . . . . . . . . . . . . . . . . . | 55% |
| Traffic; abundance of cars and trucks . . . . . . | 53 |
| Respiratory ailments; eye irritation; breathing difficulties; allergies . . . . . . . . | 28 |
| Population; dense metropolitan areas . . . . . . . . | 14 |
| Airports and planes . . . . . . . . . . . . . . . | 9 |
| Pulp and paper mills . . . . . . . . . . . . . . | 6 |
| Lumber mills . . . . . . . . . . . . . . . . . . | 4 |

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1/ Results total more than 100%, due to multiple response.

## Q26a) Reasons for Feeling Air Pollution is a Serious Problem in Home Area. (Read down) (continued)

| Reason(s): | Total Feeling Serious |
|---|---|
| Farming in general; crop dusting; smudge pots | 2 |
| Field burning specifically | 2 |
| Open burning; trash burning | 2 |
| Mine dust | 1 |
| Miscellaneous; highway construction; poor visibility; litter | 6 |
| Undecided | 1 |
| Total 1/ | 183% |
| (Sample) | (222) |

## Q27) Reasons for Feeling Oregon has More of an Air Pollution Problem than Hometown. (Read down)

| Reason(s): | Total Feeling More |
|---|---|
| More industry; canneries | 39% |
| Lumber mills; saw mills; timber industry | 31 |
| Field burning | 18 |
| Paper mills | 17 |
| Cars and trucks | 14 |
| More population; greater urban areas | 11 |
| Open burning; backyard trash burning; smoke | 7 |
| Respiratory ailments; physically bad; can see and smell pollution | 4 |

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1/ Results total more than 100%, due to multiple response.

## Q27) Reasons for Feeling Oregon has More of an Air Pollution Problem than Hometown. (Read down) (continued)

| Reason(s): | Total Feeling More |
|---|---|
| Less wind; hometown at higher elevation | 4 |
| Miscellaneous; air just isn't clean; can't see | 8 |
| Undecided | 3 |
| Total 1/ | 156% |
| (Sample) | (71) |

## Q27) Reasons for feeling Oregon has Less of an Air Pollution Problem than Hometown. (Read down)

| Reason(s): | Total Feeling Less |
|---|---|
| Less industrial pollutants | 40% |
| Smaller population; fewer people in urban areas | 40 |
| Less traffic congestion; not as many cars | 27 |
| Rain; climate cleans air; circulation of air; sea breeze; close to ocean | 17 |
| Forests; trees consume carbon; high mountains | 6 |
| No respiratory ailments | 4 |
| Fewer lumber and paper mills | 2 |
| Less airports and airplane traffic | 2 |
| Not as much field burning; burning isn't harmful as are chemicals | 1 |
| Miscellaneous; absence of litter; clean roads | 2 |
| Undecided | 14 |
| Total 1/ | 155% |
| (Sample) | (245) |

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1/ Results total more than 100%, due to multiple response.

Q27) Respondent Comments on Clean Air in Oregon.
(Note: The following comments reflect persons who felt Oregon has less air pollution than where they live, but also volunteered a critical comment -- coded 5 on question 27)

When they field burn, you can't do anything about it. (M, 50-59, Investment Broker, Washington)

Oregon is less industrialized, but there isn't so much field burning in Washington. (F, 20-29, Wife of Lumber Supervisor, Washington)

The last few days I think it is a very serious problem with farmers burning. (M, 30-39, Structural Engineer, Tennessee)

The country air isn't clean in Oregon. (M, 50-59, Dentist, Texas)

The field burning is really the only problem. (F, 30-39, Wife of Carpet Layer, California)

On the whole, the state is good, but the field burning in places is bad. Albany is a poor area also. Just have these spots of field burning, which I'm sure is just for part of the year. Of course, you do have the pulp and paper mills, but they are trying to convert those to clean them up. (F, 40-49, Wife of Accountant, California)

What is that burning, anyway? At first I was feeling so sorry for all those people, but here they are doing it deliberately. There can't be any reason that could justify all this smoke. (F, 40-49, Wife of Teacher, California)

When we came in, they were burning; and the sky was not quite as clear and pretty as Vancouver, B.C. where we were just at. (F, 30-39, Wife of Advertising Agent, California)

I've seen some bad field burning here. (M, 50-59, Bus Driver, Canada)

There was that awful field burning. (F, 30-39, Wife of Electrical Contractor, California)

Here it is worse than in the same areas in Washington because we don't burn. (M, 20-29, Navy Reserve, Washington)

More Respondent Comments on Clean Air in Oregon.

The only thing we saw was the burning. We have banned outside burning, like at private residences. (M, 30-39, Teacher, California)

I had heard before that people travelling through the Willamette Valley had been disappointed because of the burning. I hope Oregon will clean the air. (M, 30-39, Teacher, California)

The fire on the farms is quite bad. (M, 30-39, Fireman, California)

Where there is field burning, the problem is much greater. (M, 30-39, Manufacturer of Burglar Alarms, California)

The only place that we have observed any pollution is below Portland about 75 miles. There is a heavy and obnoxious smoke. I wouldn't want to stop in that area. (M, 60 or over, Writer, California)